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Science Focus

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The theory that could redefine the hunt for alien worlds

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Does the virus linger in the air for long periods?

Sleep
A scientist's guide to getting a good night's rest

Veganism
Michael Mosley on the long-term risks and benefits

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The lockdown has meant my step count has dropped. Should I be worried? →p80

FROM THE EDITOR

From *Interstellar* to *Lost In Space* to *Event Horizon*, black holes have inspired a wealth of science fiction. But now there's a new idea in cosmology that's so out there it seems as though it could have been plucked from an episode of *Star Trek* itself.

In the hunt for alien life, some scientists think we might be taking an approach that's too conventional. Usually, we look for solar systems like our own: a set of planets basking in the warmth of star. But we might have overlooked a potential location that's a bit more… heavy metal.

What if black holes, which are known for being forces of destruction, could harbour life in their midst? What if the matter and energy swirling towards the event horizon could actually provide enough warmth to cultivate biology? Scientists are modelling precisely this, and the results are pretty surprising. Head to p54 to find out more.

If you enjoy reading about black holes and are hankering after some more mind-bending physics, you need to subscribe to our podcast. Head to **sciencefocus.com/podcast** to find our six-part mini-series on physics with Prof Jim Al-Khalili, and tonnes of other great interviews about space travel, nanotechnology, medical science and much more.

Enjoy the issue!

Daniel Bennett, Editor

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DR PRAGYA AGARWAL
As the world addresses public memorials, behavioural scientist Pragya explains how things in our environment influence our national identity. →p36

DR RACHEL BROWN
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ON THE BBC THIS MONTH...

Planet Earth: A Celebration
Featuring eight breathtaking scenes from *Planet Earth II* and *Blue Planet II*, this special programme will be accompanied by a brand new score from Hans Zimmer and the string section of the BBC Concert Orchestra.
BBC One, check *Radio Times* for details

The Life Scientific
This month, Prof Jim Al-Khalili is discussing bones with Prof Alice Roberts (pictured below), marine conservation with Dr Heather Koldewey, and how to feed the world's growing population with plant scientist Prof Dale Sanders.
BBC Radio 4, Tuesdays at 9am

Animal Park
It has been 20 years since Ben Fogle and Kate Humble first introduced us to the team from Longleat Estate and Safari Park, and this summer we're invited behind the scenes once again. Find out how the pandemic has affected the park, witness newborn armadillos' first moments, and meet the ostrich who thinks it's a zebra...
BBC One, check *Radio Times* for details

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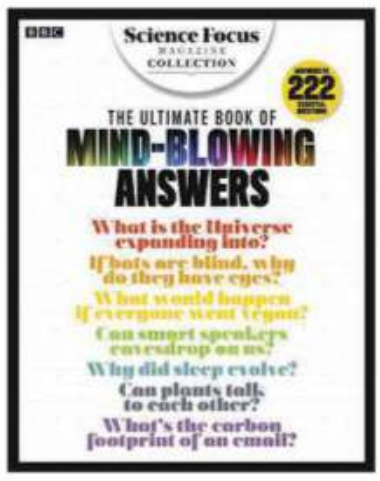
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Why did sleep evolve?
Can plants talk to each other?
What's the carbon footprint of an email?

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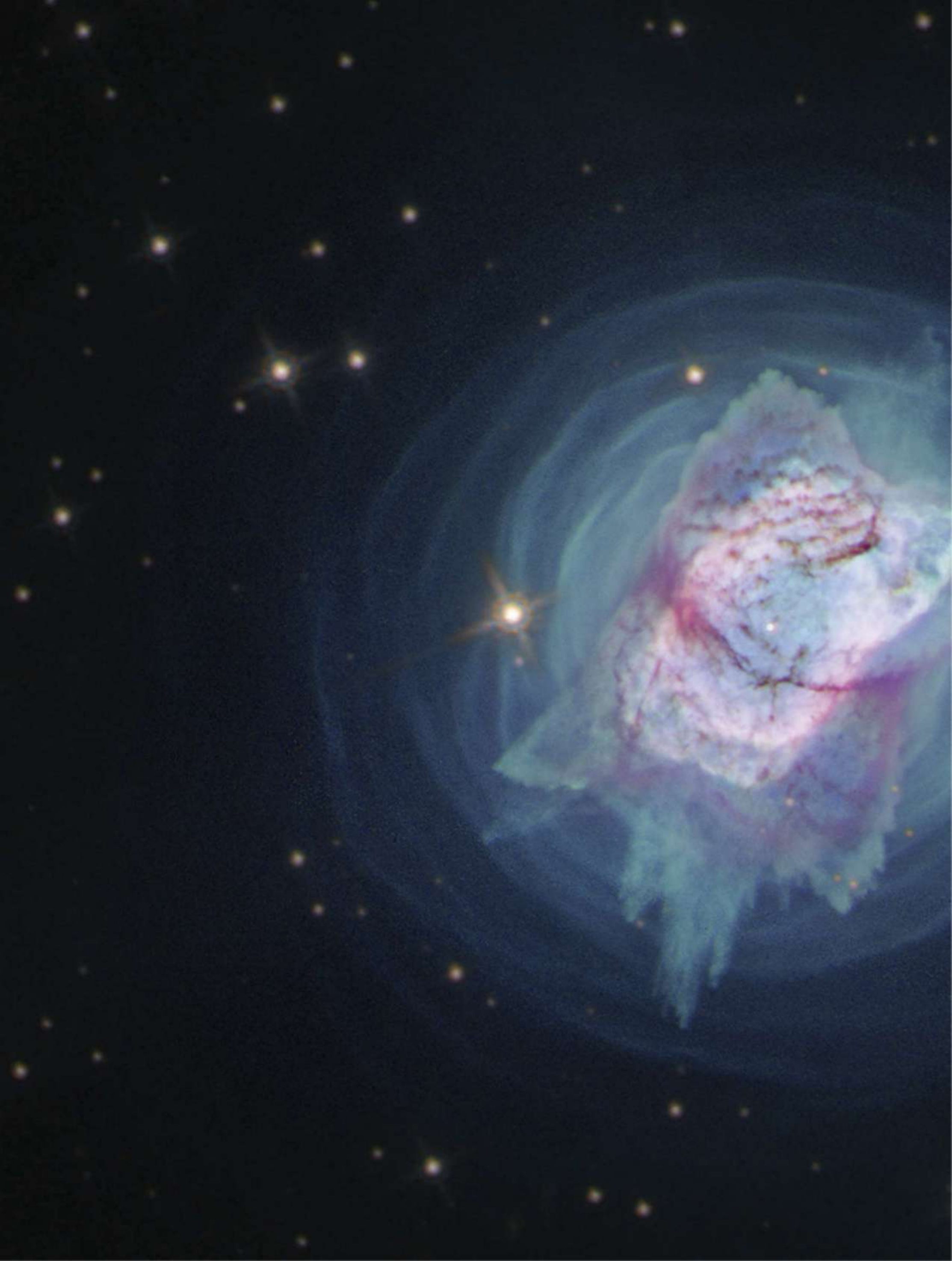

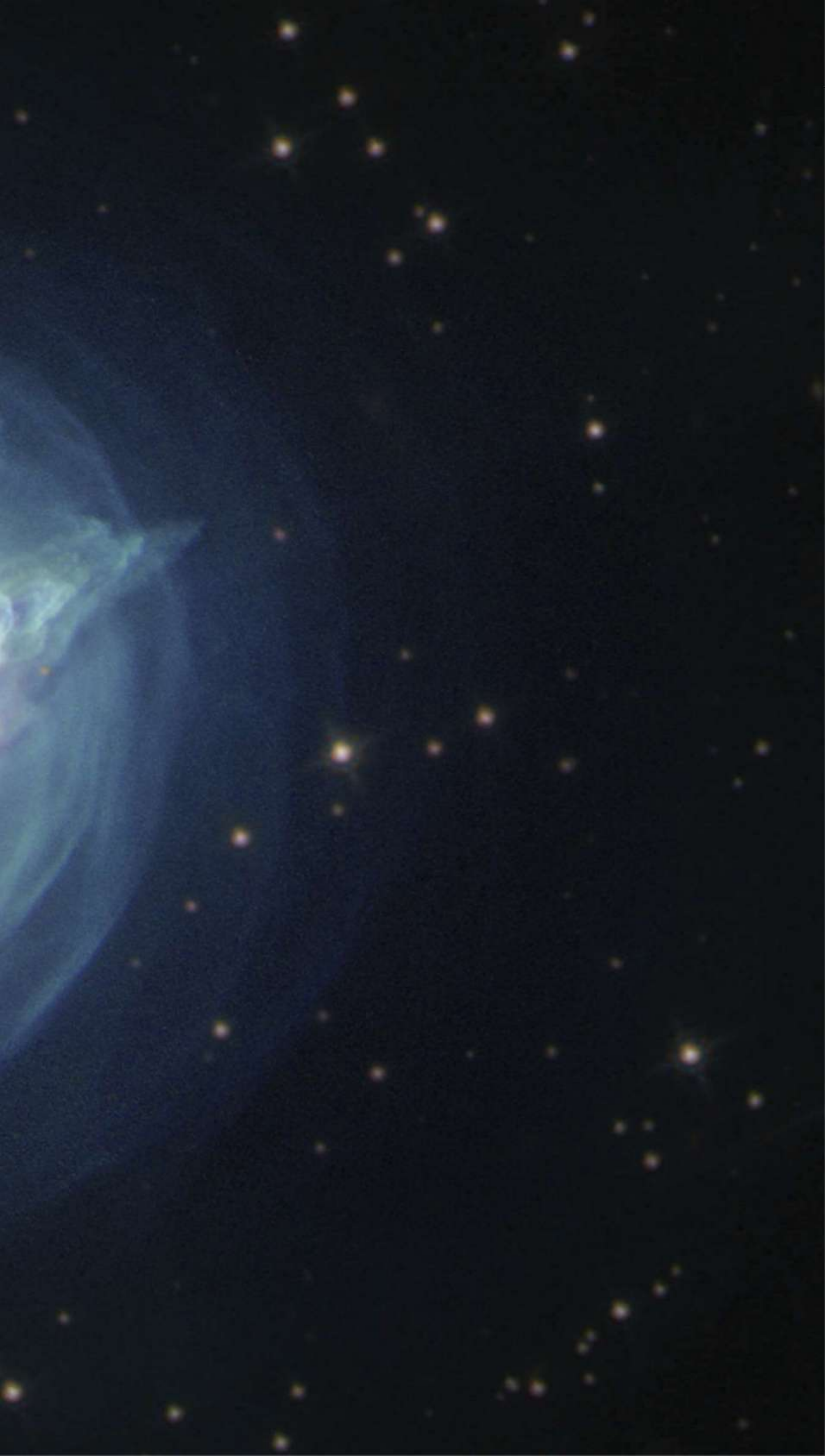

EYE OPENER

Hubble bubble

HUBBLE SPACE TELESCOPE

This brightly coloured, glowing bubble of gas and dust is the planetary nebula, NGC 7027. It measures just 0.2 by 0.1 light-years in size, and is one of the smallest and brightest planetary nebulae. It is located some 3,000 light-years away in the Cygnus constellation.

Planetary nebulae are formed when ageing stars shed their outer layers of gas into space. New images from the Hubble Space Telescope will allow researchers to study NGC 7027 in the near-ultraviolet wavelength for the first time, which may help unlock some of the mysteries of this object.

One theory is that a closely orbiting binary star has been sloughing off material for thousands of years, seen here as blue rings, but now the nebula has entered a more violent phase. It's ejecting hot gas and dust in specific directions, creating its pointed 'corners', seen here in red.

NASA/ESA/J KASTNER (RIT)

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EYE OPENER

Meat the future

REHOVOT, ISRAEL

Meat has one of the largest carbon footprints of any food. A diet that contains meat releases the equivalent of 4.7 to 7.2kg of CO_2 every single day (*BBC Science Focus*, April 2020). As the global population continues to rise, there are serious concerns around whether the demand for meat can be sustained in the coming decades.

Could 3D-printed, synthetic meat be a viable alternative? Israeli start-up Redefine Meat thinks so. The company aims to reproduce not a generic meat-tasting product, but a steak with all the appearance, texture and flavour of whole muscle meat, using raw ingredients sourced from plants. Combined with food-printing technology using custom-made 3D printers, the 'meat' will have a 95 per cent smaller environmental impact than the real thing.

If Redefine Meat pulls this off on a commercial scale, we'll be a step closer to *Star Trek* replicators becoming reality.

REUTERS

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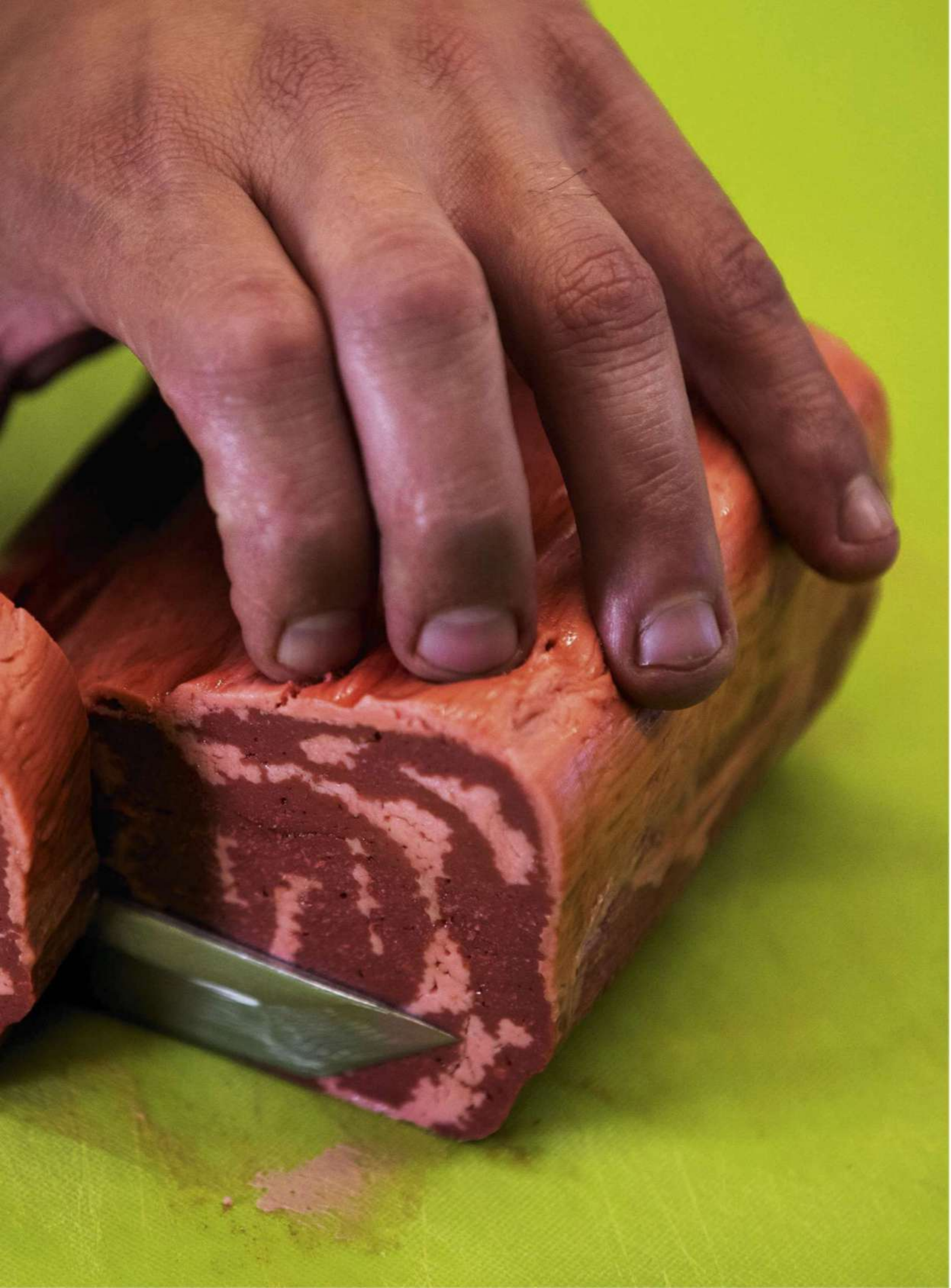

EYE OPENER

Bionic brilliance

GAZIANTEP, TURKEY

This is Zübeyde Nisa Karabacak and her bionic arm, which she's nicknamed 'Revo'. It's an i-Limb Ultra Revolution, an electric prosthesis that she controls with signals from her muscles. Delicate electrodes in the wrist pick up electrical impulses created as the muscles on her residual arm contract, which are then passed as commands to a tiny computer that activates the hand. It's also the first prosthesis that can be controlled by smartphone app.

There are 24 pre-programmed commands, such as 'handshake' and 'grasp computer mouse', but she can also create her own. Individual motors in each of the digits provide her with precise control.

At first, she was only able to complete simple housework tasks. Now, Revo is a big part of her daily life and she can play the violin, paint and even apply nail varnish.

Karabacak, who lost part of her arm in a traffic accident back in 2016, says, "life begins now".

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LETTER OF THE MONTH

Ride and dine

At the risk of sounding at best a bit weird and at worst completely barking, I have always been fascinated by cheese, ever since I was forced to watch *White Christmas* as a child and Bing Crosby explained how different cheeses can affect your dreams. I have, in the past, eaten particularly pungent cheeses at bedtime in the hope of dreaming the winning lottery numbers.

In your July issue (p66), Dr Farrimond explained why some people like strong cheeses and why we have a 'taste' for danger foods. This idea linked to the dopamines mentioned in the piece on rollercoasters in that same issue (p70). Perhaps I could launch a gourmet thrill experience in partnership with a theme park. Puffer fish (illegal in the UK), then a stinky cheese board, followed by kopi luwak (civet poo) espresso, then an intense white-knuckle ride.

The only drawback is that the cleaning bill for the rollercoaster cars would be astronomical...

Simon Elson, *Burton-on-Trent*

WRITE IN AND WIN!

The writer of next issue's *Letter Of The Month* wins a **Logitech MK470 wireless keyboard and mouse combo**. This stylish, ultra-thin, minimalist design packs easily into your bag for working on-the-go, and ensures your desk setup is smart and unobtrusive, whether you're in an office or at the kitchen table. With 18 months of battery life for the mouse and 36 months for the keyboard, you won't need to worry about unexpectedly losing power either. **logitech.com**

Cheesed off

I note with amusement you have been talking about cheese and how brains love it (July, p66). How about those of us that cannot stand the stuff? What are we missing? To me, it is disgusting in any form, no exceptions – like eating something gone bad!

Thomas Stanley

What's up with that?

In April's *What Hubble Taught Us* (p51), it said that astronomers are questioning why the Universe is still expanding, when it should be slowing down or at a plateau. "We still don't really understand," quotes Jennifer Wiseman.

Surely, unless I'm missing something, the Universe simply hasn't reached that point. By what calculation has science deemed that we've reached the plateau?

Murray Cornwell, *Florida*

It's not surprising that the Universe is still expanding, as you said. We would expect that the Universe exploded outwards at a high speed and gradually came to a stop. The confusing part is that it isn't slowing down, but speeding up!

It's like if you threw a ball up in the air, and instead of coming back down, it shot out of the atmosphere into space. That would be

"RATHER THAN GIVING EVERYONE THE SAME MEDICINE, WHY NOT GIVE THEM AN IMPLANT THAT CAN MAYBE GENERATE THE SORT OF CHEMICALS THAT THEY NEED IN THEIR BODY?"

RITU RAMAN, p66

GETTY IMAGES, SCIENCE PHOTO LIBRARY, L'OREAL USA

surprising – and hint that there was something strange going on.
Sara Rigby, *online assistant,* BBC Science Focus

Advertise your morals

In the March edition of *BBC Science Focus*, I was surprised to discover an advertisement for Princess, a major cruise ship company, displayed on the back of the issue. As this magazine is predominantly focused on science – frequently featuring a section titled *Green Papers* that promotes awareness of global warming – I would assume *BBC Science Focus* were more than aware of the obvious detrimental effects of cruise liners. Therefore, I found the fact that a corporation with such a negative environmental impact had been publicised a little immoral, to say the least. I was wondering why *BBC Science Focus* would choose to display an advert like this?
Phoebe Cullen, *East Sussex*

Thank you for getting in touch, Phoebe. As with many publications, advertisements published are not an endorsement of the products. To turn away adverts that are legal and truthful (as mandated by the Advertising Standards Authority) from selected advertisers on the basis that they offer foreign travel, yet accept advertising for the local UK travel industry, would be against the BBC rules on bias. Advertisements are an important revenue stream for the magazine industry, and without them many publications would be forced to close.
Emma Cooney, *Immediate Media (publisher of* BBC Science Focus*)*

On the 5:2 diet

Dr Michael Mosley has previously mentioned the 5:2 diet as a way to improve your health and longevity and I agree with the science. But for people like me who have delicate stomachs, and can't hack big changes in diet on a weekly basis, would a restricted diet over four consecutive days in a month be as good?
Andrew Cirel

When I wrote *The Fast Diet,* I suggested a range of different ways to do intermittent fasting, as well as 5:2. You may find it easier, particularly if you have a delicate stomach, to try time-restricted eating, where you eat within a particular time window, such as 14:10. An example of this would be to stop eating and drinking anything with calories by 8pm, and not eat again until 10am the next morning. You might want to check out the work of Prof Satchin Panda, of the Salk Institute in California: mycircadianclock.org
Dr Michael Mosley, BBC Science Focus *columnist*

Oops...

I don't wish to add to the infamous stereotype of nitpicky *Star Trek* fans, but the error made in your *Is Warp Drive Really Possible?* article (July, p33) is unforgivable. In the opening line, it states 5 April, 2063 as the date the *Enterprise* 'ventures into the Galaxy' – but the *Enterprise* (actually launched in 2245) wasn't even a twinkle in Kirk's eye at this time! The date you mentioned is in fact 'First Contact Day', when the *Phoenix*, the actual first FTL capable ship, took flight. Is it time for a *Star Trek* rewatch?
Al De Libero

What can I say? I apologise wholeheartedly, as I inadvertently added this error during the editing process. I'm hanging my head in shame. Rest assured, I'll start bingeing on *Star Trek* to brush up on my knowledge.
Alice Lipscombe-Southwell, *managing editor,* BBC Science Focus

Oops...

Dr Michael Mosley's column (Summer, p63) stated that research into mental health during the lockdown was carried out by researchers at the University of Exeter. This should have read the University of Essex!

THE TEAM

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ANNUAL SUBSCRIPTION RATES (INC P&P):
UK/BFPO £72.80; Europe & Eire £77.80; Rest of World £82.80.

Audit Bureau of Circulations
44,687 (combined, Jan-Dec 2019)

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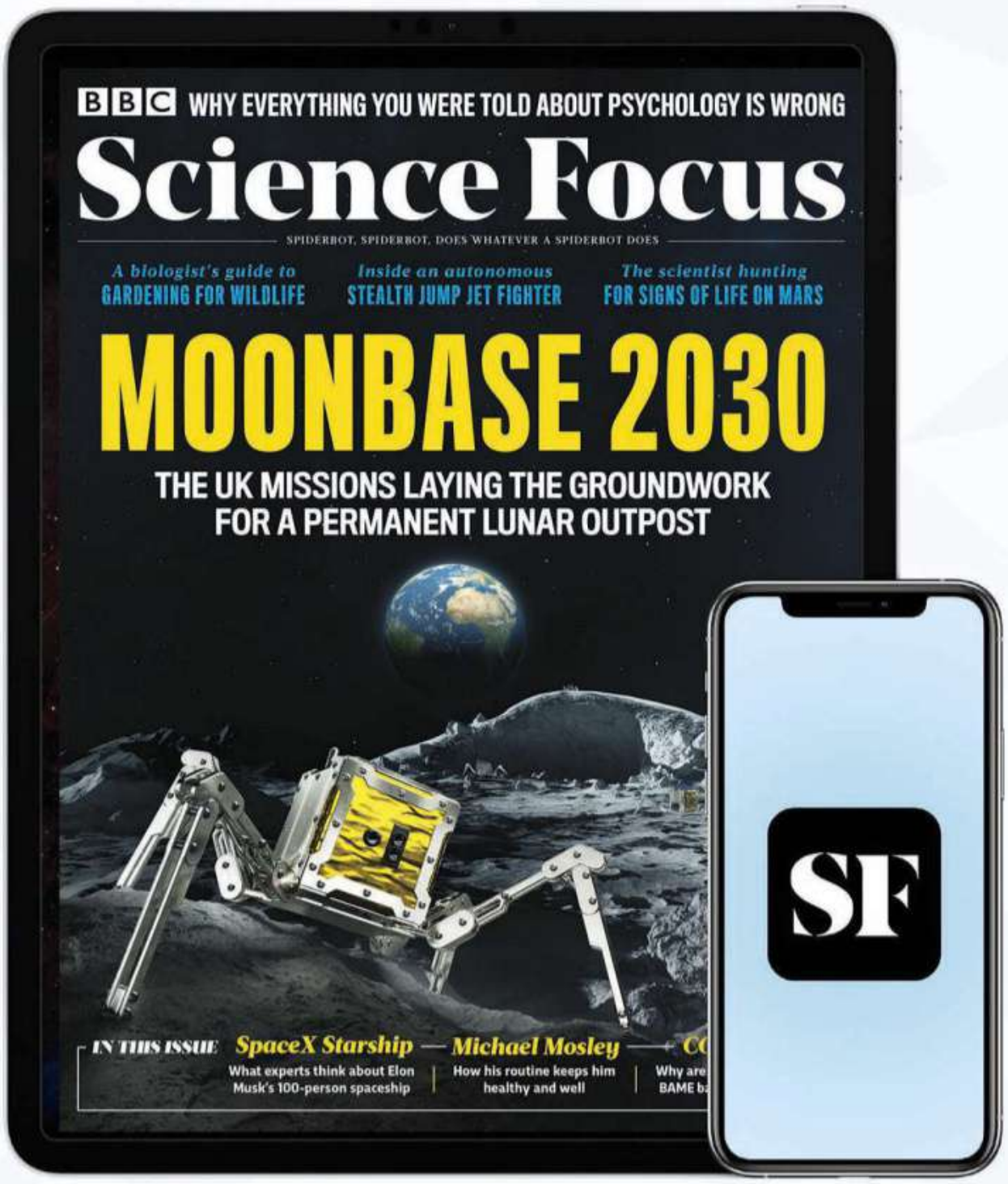
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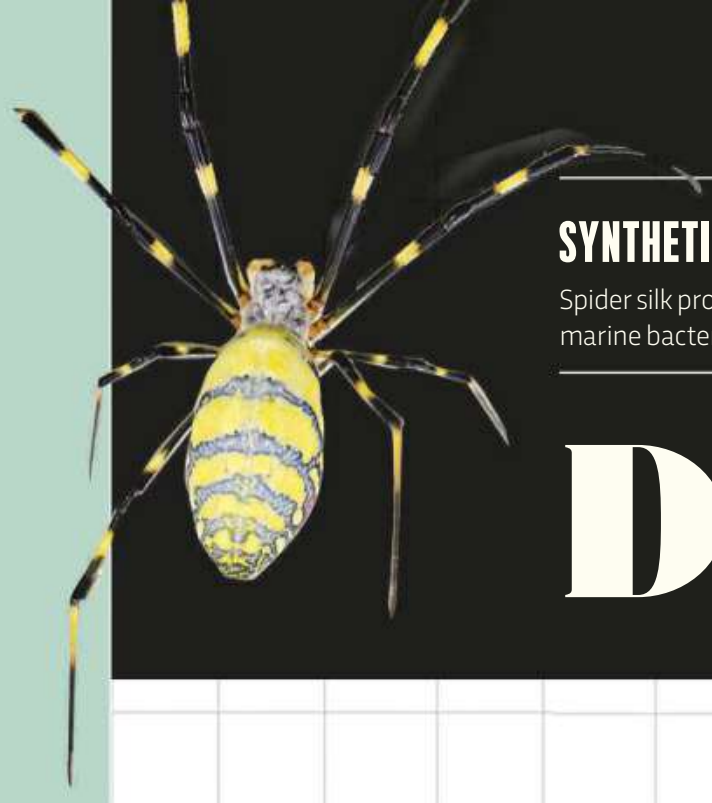

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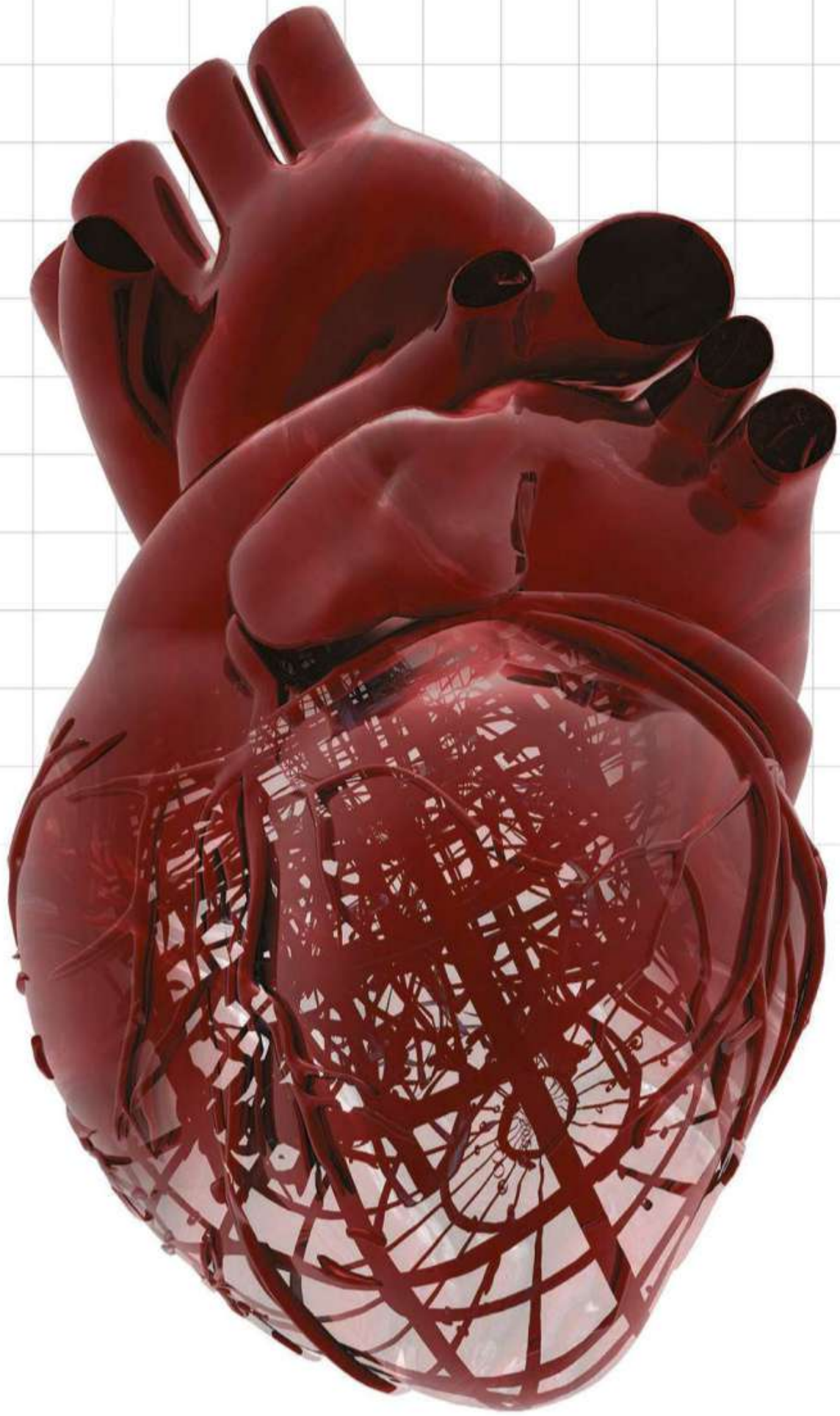
MINIATURE HUMAN HEART 3D PRINTED USING STEM CELLS



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The breakthrough could have major implications in the study of heart disease

According to the British Heart Foundation, heart and circulatory diseases cause more than a quarter of all deaths in the UK; that's nearly 170,000 deaths each year. In a new study, researchers at the University of Minnesota have created a functioning centimetre-scale human heart pump using 3D printing techniques, which could have major implications in the fight against heart disease.

In previous studies, researchers had tried to 3D print heart muscle cells, called cardiomyocytes, using pluripotent human stem cells – cells with the potential to develop into any type of cell in the body. They would programme these cells to form heart muscle cells, then with specialised 3D printers, deposit the cells within a scaffold structure called an extracellular matrix. Though promising, this method never produced cells dense enough for the heart muscle to function.

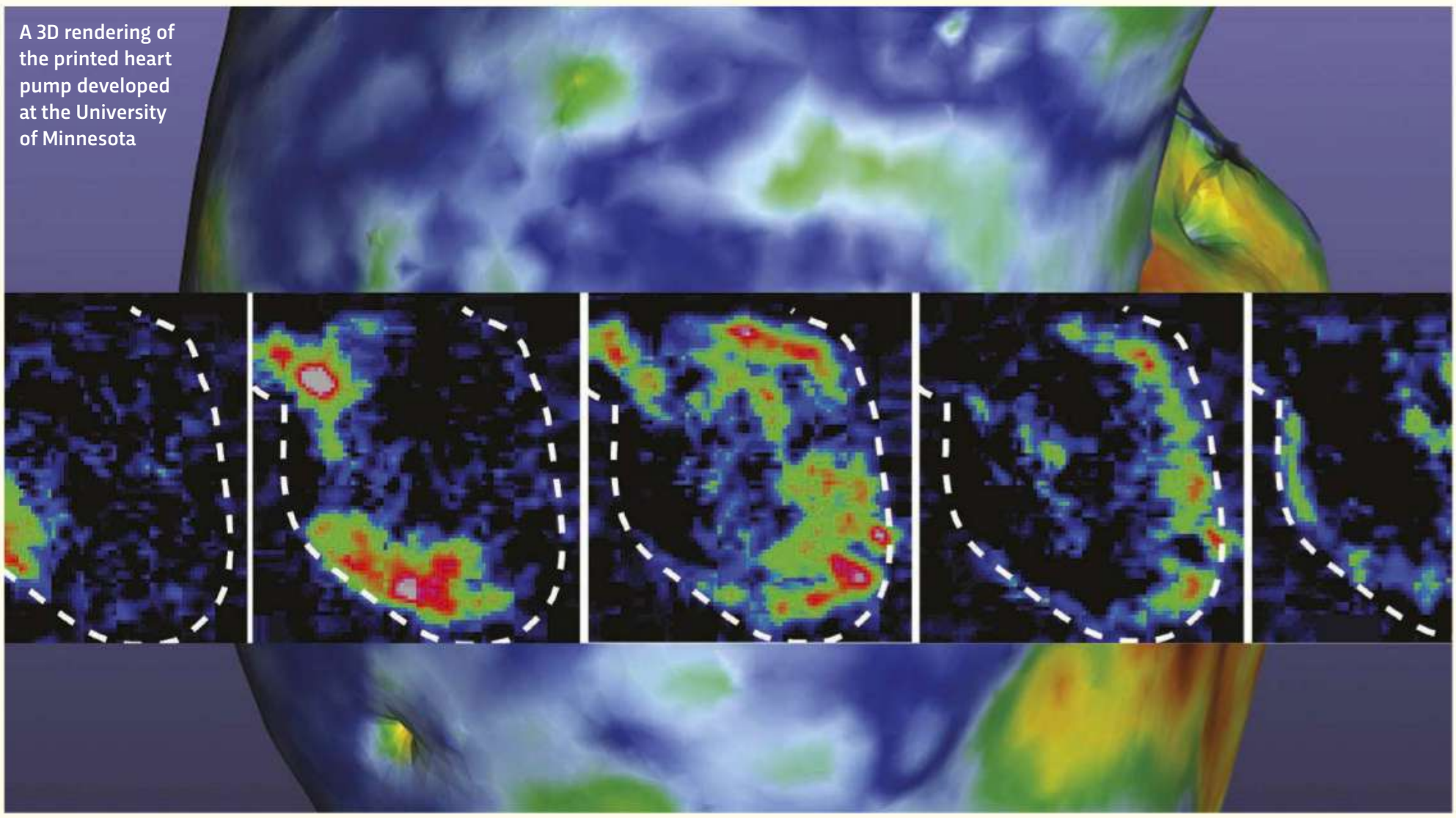
To get around this issue, the University of Minnesota researchers

Whale hello! Beluga whales have surprisingly complex social structures p22 **Coffee cup creature** Meet the tiny relative of the dinosaurs p18 **Weightlifting monkeys** How does working out affect neural strength? p22

News in brief

FOXES HAVE BEEN EATING OUR LEFTOVERS FOR 42,000 YEARS

While it may feel like a very modern problem to wake up in the morning and find your rubbish bins scavenged by foxes, these sly critters have been dining on human leftovers for tens of thousands of years, researchers at the University of Tübingen, Germany have found. The team compared isotope ratios between the remains of various red and Arctic foxes from several archaeological sites in southwest Germany dating to the Middle and Upper Palaeolithic. They found that from around 42,000 years ago, foxes' diets began to heavily feature reindeer, which were too big for foxes to hunt but were known to have been important game for humans of the time.



A 3D rendering of the printed heart pump developed at the University of Minnesota

flipped the process around. "The stem cells were expanded to high cell densities in the structure first, and then we differentiated them to the heart muscle cells," said Prof Brenda Ogle, the lead researcher and head of the Department of Biomedical Engineering in the University of Minnesota College of Science and Engineering.

Using this method, they found that they could reach high enough cell density within less than a month to allow the cells to beat together, just like a human heart.

"I couldn't believe it when we looked at the dish in the lab and saw the whole thing contracting spontaneously and synchronously and able to move fluid," said Ogle.

The heart muscle model is about 1.5 centimetres long and was specifically designed to fit into the abdominal cavity of a mouse for further study. It is like a closed sac featuring a fluid inlet and outlet, allowing researchers to measure how a heart moves blood within the body.

"I couldn't believe it when we looked at the dish and saw the whole thing contracting spontaneously and synchronously"

"We now have a model to track and trace what is happening at the cell and molecular level in pump structure that begins to approximate the human heart. We can introduce disease and damage into the model and then study the effects of medicines and other therapeutics," explained Ogle. "All of this seems like a simple concept, but how you achieve this is quite complex. We see the potential and think that our new discovery could have a transformative effect on heart research."

ACTIVE MUMS TO BE
Moderate exercise, like going for a walk, during pregnancy can help increase the presence of a beneficial compound called 3SL in breast milk. The compound has been found to reduce a baby's risk of serious health issues, researchers at Ohio State University have found.

DESK WORKERS
People in jobs that require less physical activity are at a lower risk of poor cognition later on, researchers from the University of Cambridge suggest. This is potentially as desk jobs are more mentally challenging, they say.

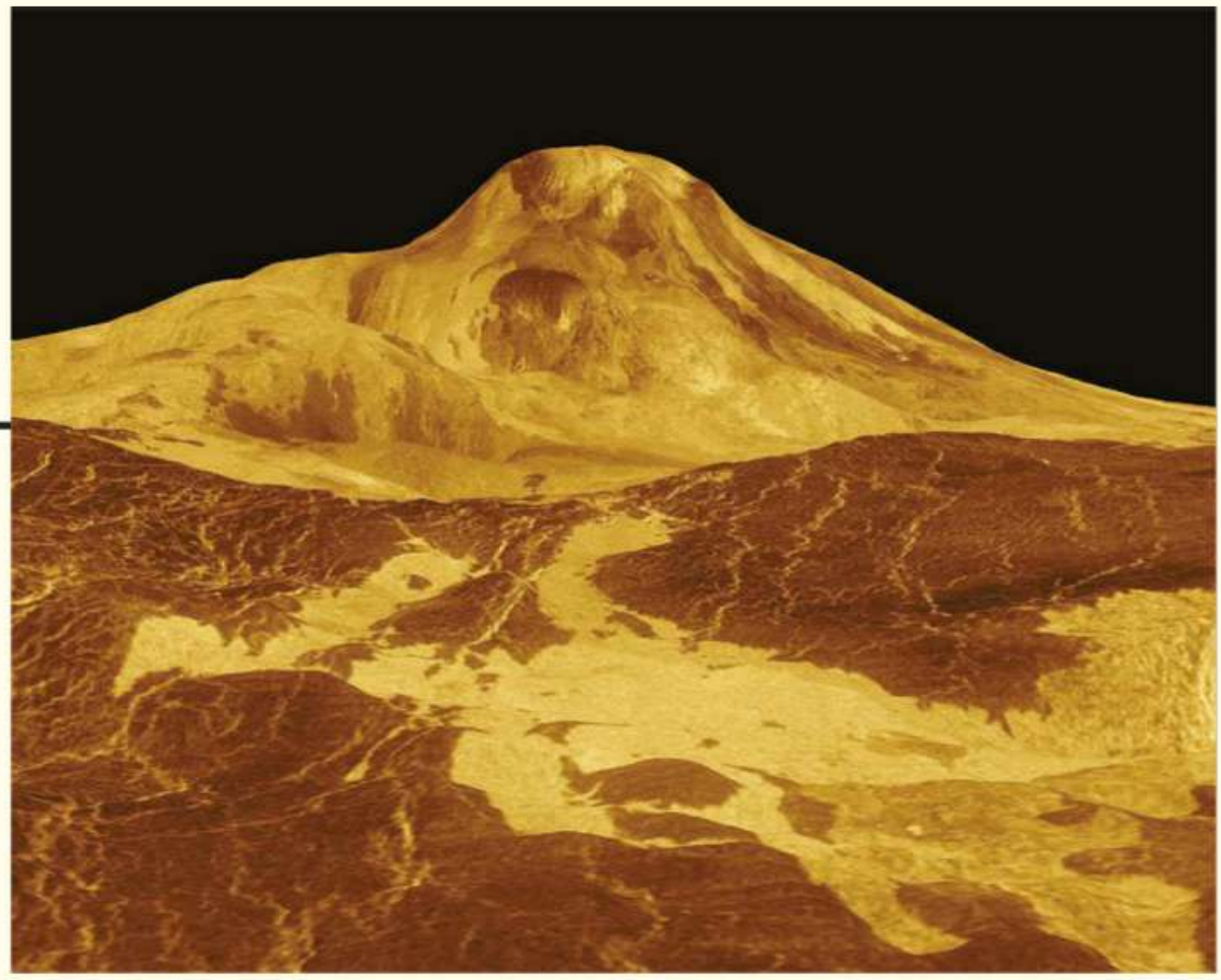
Good month

Bad month

THE UPPER CLASS
Those from wealthy backgrounds tend to be unaware of their class privilege and are more likely to attribute their high income to personal struggle and hard work, a study from New York University suggests. "The ideology of meritocracy motivates people to claim hardship, potentially blinding themselves and others to the privileges of class," the authors said.

TRUANTS
Kids who miss a lot of school early on are less likely to vote, have greater economic difficulties and have poorer educational outcomes when they are young adults, a study at Ohio State University has found.

KUPFER/LIN ET AL/UNIVERSITY OF MINNESOTA, ALAMY, NASA/JPL ILLUSTRATIONS: CATHAL DUANE



SPACE

Recently active volcanoes identified on Venus

Venus is home to at least 37 recently active volcanic structures, a study by researchers at the University of Maryland and the Institute of Geophysics at ETH Zurich has found. This is the first evidence that the interior of the planet is still geologically active.

Previous studies have discovered evidence of a warm interior and ring-like structures known as coronae. Coronae form when plumes of hot material deep inside the planet rise through the mantle layer and crust, in a manner similar to the way that mantle plumes formed the volcanic Hawaiian Islands.

It was originally thought that they were signs of ancient activity, and that the planet had cooled enough to slow down the geological activity in the planet's interior, hardening the crust so much that any warm material from deep inside would not be able to puncture through.

In the new study, the researchers created models of the thermal activity beneath the surface to create high-resolution, 3D simulations of coronae formation. They then used these to identify features that are present only in recently active coronae and looked for similar structures on the surface of Venus.

"This is the first time we are able to point to specific structures and say, 'Look, this is not an ancient volcano but one that is active today, dormant perhaps, but not dead,'" explained Laurent Montési, a professor of geology at the University of Maryland. "This study significantly changes the view of Venus from a mostly inactive planet to one whose interior is still churning and can feed many active volcanoes."

The active coronae on Venus are clustered together in a handful of locations, which suggests hotspot areas where the planet is most geologically active. This may help identify target areas where geologic instruments should be placed on future missions to Venus, such as Europe's EnVision that is scheduled to launch in 2032.

FOOD TO IMPROVE YOUR MOOD: PROBIOTICS MAY HELP IN THE FIGHT AGAINST DEPRESSION

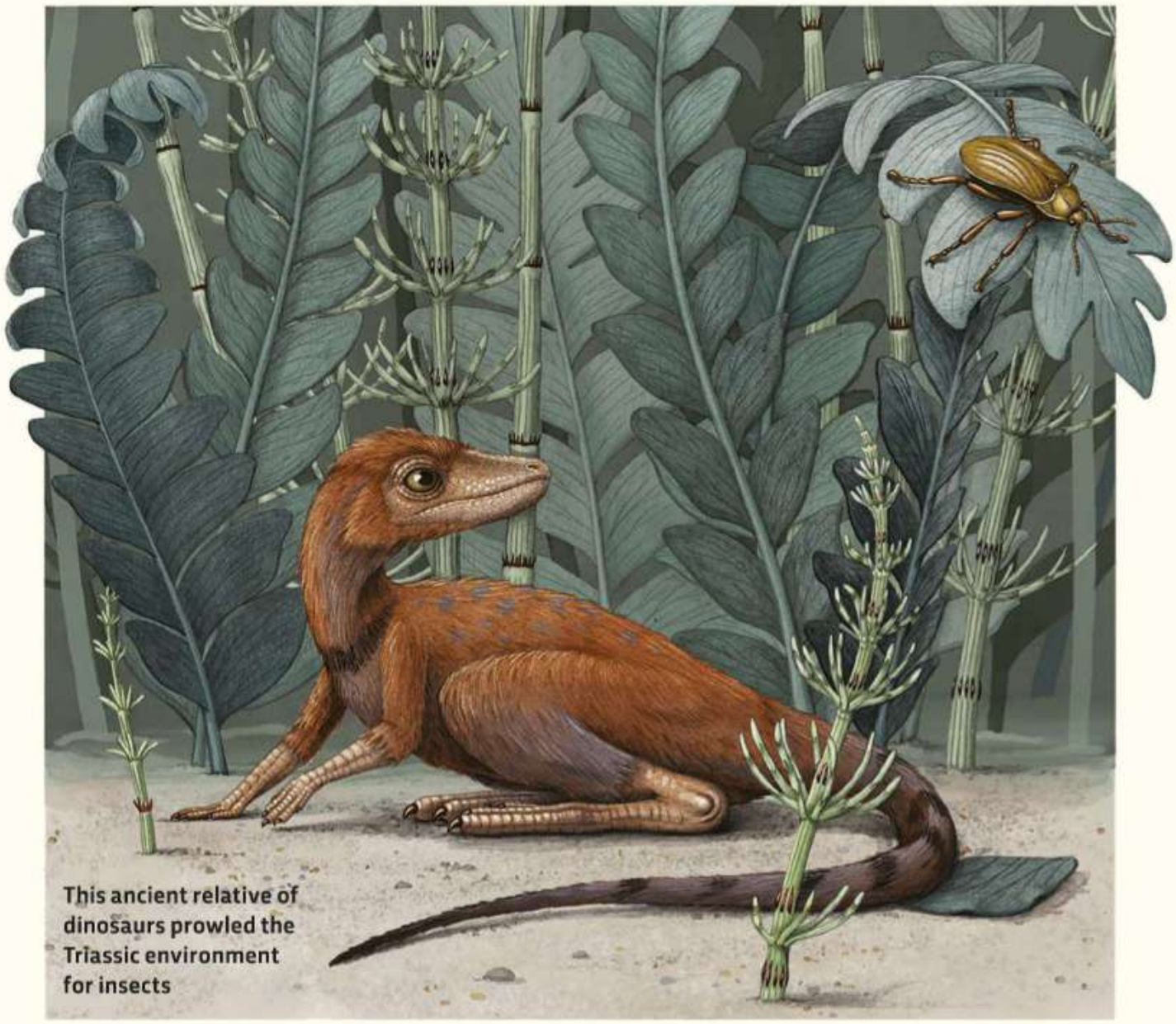
It has been known for some time that the microbiome – the colony of bacteria that resides in the gut – might help treat mental illnesses, thanks to the two-way relationship that exists between the brain and digestive tract, known as the gut-brain axis. Now, a review carried out by researchers at Brighton and Sussex Medical School, which looked at 71 studies published between 2003 and 2019, has found that probiotics (good bacteria) and prebiotics (substances that promote the flourishing of these bacteria), may help ease the symptoms of depression. The effect could be down to probiotics helping to reduce the production of inflammatory chemicals, or they may be affecting the action of tryptophan, a chemical thought to be important in the gut-brain axis in psychiatric disorders, the researchers said.

PALAEONTOLOGY

Meet the 'tiny bug slayer', a coffee-cup-sized relative of the dinosaurs

Dinosaurs and flying pterosaurs are some of the largest animals that ever lived, but a newly described fossil from Madagascar suggests that their ancestors were surprisingly small.

The fossilised reptile, which lived around 237 million years ago, has been named *Kongonaphon kely*, or 'tiny bug slayer' (derived from both Ancient Greek and the Malagasy language of Madagascar). The creature stood only 10 centimetres tall – about the size of a coffee cup.



This ancient relative of dinosaurs prowled the Triassic environment for insects

K. kely dates from the time in the Triassic when the dinosaurs and pterosaurs, which both belong to a group called 'Ornithodira', branched into separate evolutionary paths.

"There's a general perception of dinosaurs as being giants," said Dr Christian Kammerer, a palaeontology curator at the North Carolina Museum of Natural Sciences, who took part in the research. "But this new animal is very close to the divergence of dinosaurs and pterosaurs, and it's shockingly small."

Few fossils exist from the time of this split, so it's been difficult to pin down what the last common ancestors of the dinosaurs and pterosaurs would have looked like.

Now, *K. kely* has provided evidence for what the researchers call a 'miniaturisation event': a sharp decrease in the ancestors' body size, before the dinosaurs and pterosaurs eventually evolved to be much bigger.

Wear and tear on the reptile's teeth suggest that it ate insects. This diet may have helped it to survive, as it occupied a different niche from its mostly meat-eating relatives.

And its discovery may also help to explain the evolution of fuzz and feathers in dinosaurs and pterosaurs. It's thought that the Triassic habitat that *K. kely* lived in would have been prone to sudden shifts in temperature between the days and nights. A growth of fuzzy down might have helped it to regulate the heat in its tiny body.

Whether you love or hate spiders, their silk has fascinating properties

BIOLOGY

Genetically modified marine bacterium can produce synthetic spider silk

A marine bacterium has been genetically engineered to produce spider silk, which has many applications in the medical, aerospace and clothing industries.

The silk that spiders use to form the spokes of their web is called dragline silk, and it's tough, lightweight and biodegradable. It's also biocompatible, which means it works well with living tissue and is not attacked by an animal's immune system, making it a sought-after material. It can be used for applications such as durable materials, drug-delivery systems, implant devices, and scaffolds for tissue engineering.

One spider can only produce trace amounts of spider silk, and because the arachnids are territorial and often cannibalistic, it's not possible to breed large groups for this purpose. Teams around the world have therefore tried to find a way to generate large quantities of spider silk in the lab.

So far, researchers have successfully used plants, animal cell cultures, yeasts, and other insects to produce a silk similar to that found in nature. However, these methods are expensive to manufacture on a large scale.

Scientists at Japan's RIKEN Center for Sustainable Resource Science concentrated their research on the purple-coloured bacterium *Rhodovulum sulfidophilum*, which is photosynthetic. It only needs seawater, a source of sunlight, carbon dioxide and nitrogen to survive. As these are all abundant, the bacterium is perfect for producing a 'bio-factory'.

> "Spider silk can be used for durable materials, drug-delivery systems and implants"

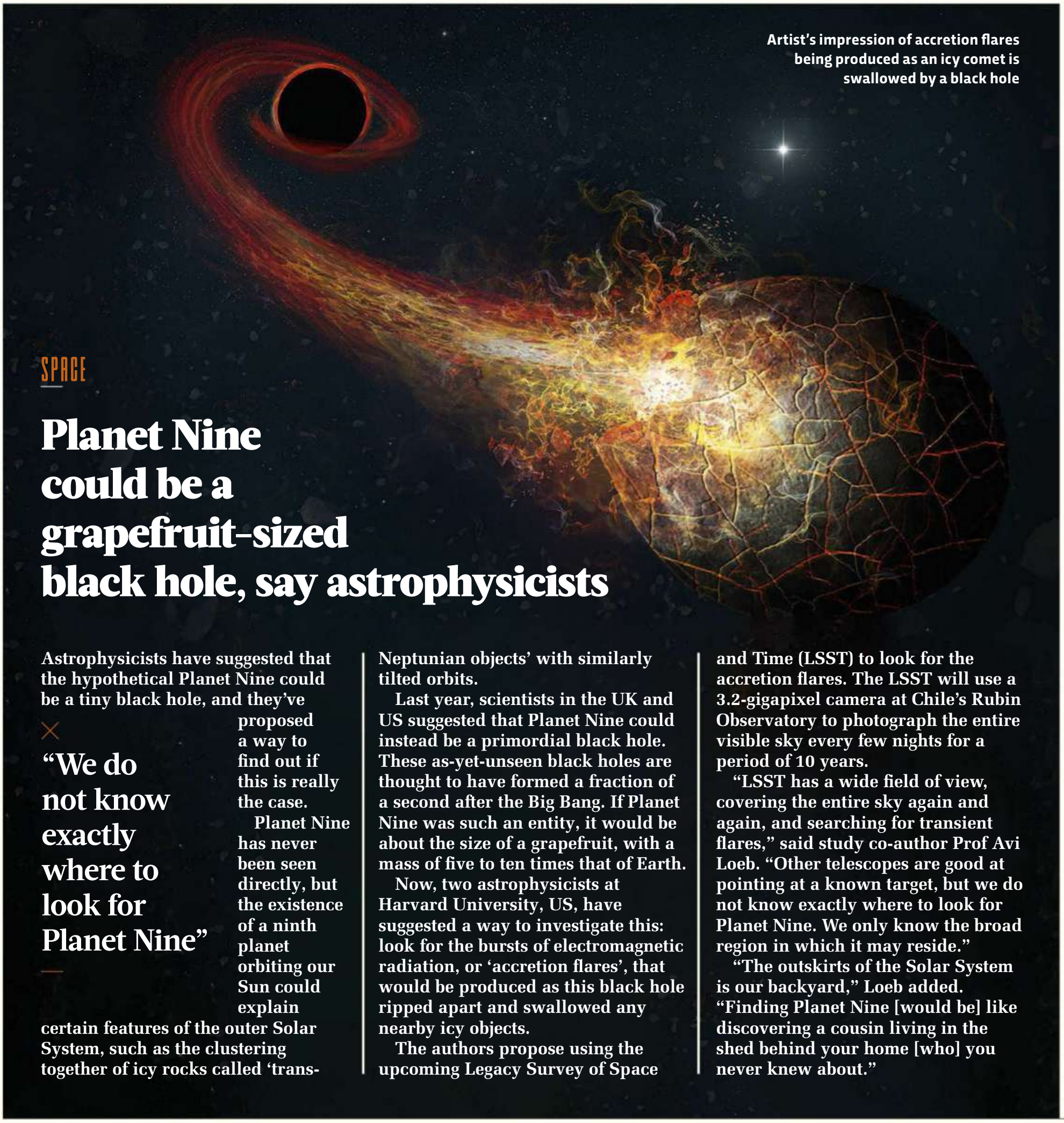
In the study, *R. sulfidophilum* was genetically modified to produce a small amount of the protein chain that makes up dragline silk. By tweaking the conditions the *R. sulfidophilum* was kept in, the researchers could encourage it to grow well and produce silk efficiently. According to Keiji Numata, who led the research, the process is carbon-neutral, making it eco-friendly and sustainable.

"We are now working to mass produce spider-silk dragline proteins at higher molecular weights in our photosynthetic system," said Numata.

GETTY IMAGES, RIKEN, ALEX BOERSMA

GLASSES FOR THE COLOUR BLIND REVEAL A WHOLE WORLD OF COLOUR

Colour blindness, or colour vision deficiency, is fairly common, affecting around 1 in 12 men and 1 in 200 women. Individuals who are unable to distinguish between different shades of red, yellow and green have what is known as red-green colour vision deficiency. Researchers at the University of California have designed glasses with lenses fitted with a filter that can increase the separation between the colours' wavelengths. Participants who wore the glasses for two weeks were able to distinguish between different colours more easily, even after taking them off. "When I wear the glasses outside, all the colours are extremely vibrant and saturated, and I can look at trees and clearly tell that each tree has a slightly different shade of green compared to the rest," said participant Alex Zbylut.



Artist's impression of accretion flares being produced as an icy comet is swallowed by a black hole

SPACE

Planet Nine could be a grapefruit-sized black hole, say astrophysicists

Astrophysicists have suggested that the hypothetical Planet Nine could be a tiny black hole, and they've proposed a way to find out if this is really the case.

> "We do not know exactly where to look for Planet Nine"

Planet Nine has never been seen directly, but the existence of a ninth planet orbiting our Sun could explain certain features of the outer Solar System, such as the clustering together of icy rocks called 'trans-Neptunian objects' with similarly tilted orbits.

Last year, scientists in the UK and US suggested that Planet Nine could instead be a primordial black hole. These as-yet-unseen black holes are thought to have formed a fraction of a second after the Big Bang. If Planet Nine was such an entity, it would be about the size of a grapefruit, with a mass of five to ten times that of Earth.

Now, two astrophysicists at Harvard University, US, have suggested a way to investigate this: look for the bursts of electromagnetic radiation, or 'accretion flares', that would be produced as this black hole ripped apart and swallowed any nearby icy objects.

The authors propose using the upcoming Legacy Survey of Space and Time (LSST) to look for the accretion flares. The LSST will use a 3.2-gigapixel camera at Chile's Rubin Observatory to photograph the entire visible sky every few nights for a period of 10 years.

"LSST has a wide field of view, covering the entire sky again and again, and searching for transient flares," said study co-author Prof Avi Loeb. "Other telescopes are good at pointing at a known target, but we do not know exactly where to look for Planet Nine. We only know the broad region in which it may reside."

"The outskirts of the Solar System is our backyard," Loeb added. "Finding Planet Nine [would be] like discovering a cousin living in the shed behind your home [who] you never knew about."

BEAVERS COULD DEGRADE PERMAFROST

Alaskan beavers are contributing to the decline of the Arctic permafrost at an 'exponential' rate, a study carried out by researchers at the University of Alaska, Fairbanks has found. Permafrost is a layer of soil, rocks and ice that has remained frozen for at least two years. Permafrost locks up greenhouse gases, so if it degrades, methane and carbon can leach into the atmosphere. In the northern hemisphere, almost a quarter of land has permafrost underneath. Over the last few decades, researchers have noticed beaver populations spreading to previously uninhabited regions of Alaska, creating dams and new lakes. As these bodies of water are warmer than the surrounding soil, it can cause the permafrost underneath them to thaw.

In numbers

40°C

The temperature UK summers could routinely reach by 2100, as estimated by the Met Office.

16.73 SECONDS

The duration of a lightning flash recorded in Argentina on 4 March 2019. It was recently confirmed as a new world record for the longest lightning flash by the World Meteorological Society.

£8BN

The value of precious metals dumped annually, thanks to tiny amounts present in electronic waste, according to a new UN report.

M WEISS, UC DAVIS, GETTY IMAGES X2

ENTOMOLOGY

Wasp 'bodyguards' could help reduce chemical pesticide use

The natural ability of some maize plants to resist insect attack could be harnessed as a biological pesticide, according to new research led by Keele University.

Pests can cause devastating losses to crops, but some maize plants will send out a chemical signal when a 'stemborer' moth has laid its eggs on the plant, in order to recruit parasitic wasps that lay their eggs in the moth caterpillars.

To find out more about the genetics behind the defence mechanism, Keele University's Prof Toby Bruce, in collaboration with the International Centre of Insect Physiology and Ecology, and the International Crops Research Institute for the Semi-Arid Tropics in Kenya, investigated the genetics of 146 types of maize plants. The plants included traditional varieties of maize (known as 'landraces'), as well as inbred lines and commercial hybrids.

The plants were exposed to stemborer eggs, in order to test the 'cry for help' chemicals released and to measure how attractive they were to the wasps. They found that the wasp-attraction trait was more common in the landrace varieties, and the team also pinpointed the region on the maize's genetic code that was connected with the response.

"Farmers urgently need alternative approaches for managing crop pests, as use of pesticides is increasingly restricted by changes in legislation and evolution of pesticide resistance," said Bruce. "Here we show how biological control of pests can be enhanced in crops. We have identified regions of the maize genome associated with a 'cry for help' trait that allows crops to call in parasitic wasp bodyguards to defend them when they are attacked by pests."

As crop plants have been selectively bred and domesticated, some have become more vulnerable to insect pests. There is increasing pressure on farmers to reduce their use of chemical pesticides, and this new genetic analysis could help in the development of crop varieties that can naturally resist pests by recruiting predators.

Natural predators, like this wasp, could help us develop ways to protect crops without the need for chemicals

They did what?

Monkeys trained to weightlift

WHAT DID THEY DO?
Researchers at UCL and Newcastle University trained monkeys to pull a weighted handle using one arm, and gradually increased the weight over 12 weeks. Each day, they stimulated the monkeys' motor cortices (the motor cortex is the part of the brain that is involved in movement) and measured the electrical activity in their arm muscles.

WHY DID THEY DO THAT?
The brain controls movements using two major neural highways connected to the spinal cord: the corticospinal tract (CST) and reticulospinal tract (RST). When people start working out, they initially get stronger by increasing connections in the nervous system, not by growing bigger muscles, but the details of which connections change were unknown.

WHAT DID THEY FIND?
The more the monkeys trained, the more the electrical response from stimulating the cortex and RST increased, while the CST remained unchanged. "These results are not just relevant to bodybuilders pushing for a new PB [personal best]. If we understand the neural mechanisms of strength then we can start to think about how to help individuals suffering from a loss of strength, such as following a stroke," said co-author Dr Isabel Glover.

CETOLOGY

Complex social groupings have been observed in beluga whales across the Arctic in a groundbreaking new study

Beluga whales make friends, just like humans

As well as spending time with their close relatives, beluga whales also frequently associate with individuals they have no relation to, a study at Florida Atlantic University's Harbor Branch Oceanographic Institute has found. Belugas make friends with others outside of their family groups, and beluga communities have similarities to human societies where social networks, support structures, cooperation and cultures involve interactions between kin and non-kin.

The study brought together decades of research using molecular genetic techniques and field studies spanning 10 locations across the Arctic from Alaska to Canada and Russia to Norway. The team found that belugas form several different group types, each with associated behaviours that were consistently observed across different populations and habitats.

"Unlike killer and pilot whales, and like some human societies, beluga whales don't solely or even primarily interact and associate with close kin," said lead author Dr Greg O'Corry-Crowe. "Beluga whales exhibit a wide range of grouping patterns, from small groups of two to 10 individuals to herds of 2,000 or more, from apparently single-sex and age-class pods to mixed-age and sex groupings, and from brief associations to multi-year affiliations," he added. "This variation suggests a fission-fusion society where group composition and size are context-specific, but it may also reflect a more rigid multilevel society of stable social units that regularly coalesce and separate. The role kinship plays in these groupings has been largely unknown."

These results differ from earlier predictions that belugas have a matrilineal social system of closely bonded groups of female relatives. They also differ from the behaviour of the larger toothed whales. Killer whales, for example, form groups of both males and females with close maternal kin and they remain in them for their entire lives.

"This new understanding of why individuals form social groups, even with non-relatives, may promote new research on what constitutes species resilience and how species like the beluga whale can respond to emerging threats, including climate change," said O'Corry-Crowe.

LISA BARRY/NOAA/AFSC/MML, KAREN OSBORN/SMITHSONIAN, GETTY IMAGES ILLUSTRATIONS: CATHAL DUANE

CINNAMON MAY HELP THOSE WITH PREDIABETES

Around seven million people in the UK have prediabetes, a condition that occurs when blood sugar levels are raised and can often lead to the development of type 2 diabetes. But now, a 12-week study carried out by researchers at the Joslin Diabetes Center in Boston, Massachusetts, has found that taking a 500mg tablet of cinnamon three times a day may help to lower blood glucose levels and improve the body's response to eating a meal with carbohydrates. While the study was small, it could help inform further research.

MARINE BIOLOGY

Ultra-black deep-sea fish that can absorb 99.9 per cent of light

You might be able to apply black make-up, dye your hair a dusky tone and drape yourself in black leather, but you'll never be as goth as some species of deep-sea fish.

A team of scientists from Duke University and the Smithsonian National Museum of Natural History have found that the skin of some deep-sea fish absorbs more than 99.95 per cent of the light that hits them, making them appear ultra-black. In the dark environment in which they live, where even a tiny bit of reflected light can attract unwanted attention, this intense black colour improves their chances of survival.

Duke University's Dr Karen Osborn, who co-led the research, first discovered the incredible properties of the fish when she tried to photograph some of the specimens that she'd brought up from the deep sea. Despite high-tech equipment, she could not see any detail in the images. "It didn't matter how you set up the camera or lighting – they [the fish] just sucked up all the light," she said.

The researchers found that the secret to the ultra-black colour is melanin – the same pigment that gives human skin and hair its colour – and its distribution within the fish skin. The melanin is located inside structures called melanosomes, which are densely packed into cells on the fish skin. Thanks to the shape and arrangement of the melanosomes, any light that reaches a melanosome will be redirected towards another in the cell, to absorb it.

"These pigment-containing structures are packed into the skin cells like a tiny gumball machine, where all of the gumballs are of just the right size and shape to trap light within the machine," said Alexander Davis, a co-author of the study and doctoral student at Duke University.

So far, the researchers have found 16 species of fish that use this method to appear ultra-black in the deep sea. As the species are not closely related, it could be a relatively common strategy. It is thought that engineers could take inspiration from the fish to create ultra-black substances for sensitive optical equipment, which is currently expensive and fiddly to produce.

Some deep-sea fish, like this *Anoplogaster cornuta* absorb almost all the light, making them appear ultra-black

GREEN PAPERS

The environmental stories you need to know

Words: **Jocelyn Timperley**

GREEN SKILLS

Around one in every 10 British workers will need to retrain or reskill if the UK is to reach its goal of net-zero carbon emissions by 2050, a new analysis suggests.

Approximately three million posts would be negatively affected by the necessary shift to green jobs, said campaign group UK100, although a similar number of new green jobs would be created, following a resilient recovery to the ongoing coronavirus crisis. Polly Billington, director of UK100, said the government and industry need to ensure that recovery is not car- or carbon-led. "There is a huge opportunity here to skill up our workforce and invest in the jobs we need right now."

One way in which methane enters the atmosphere is through the burning of fossil fuels

CLIMATE CHANGE

Global methane emissions are highest on record

Elevated levels of methane in the atmosphere could lead to an increase in wildfires, droughts and flooding, researchers say

Between 2000 and 2017, levels of the potent greenhouse gas methane barrelled up toward pathways that climate models suggest will lead to between 3°C and 4°C of warming before the end of this century, researchers at Stanford University have found.

Increases are being driven primarily by the growth of emissions from coal mining, oil and natural gas production, cattle and sheep ranching, and landfills, which could lead to an increase in natural disasters, including wildfires, droughts and floods.

Methane is a colourless, odourless gas that is 28 times more powerful than carbon dioxide at trapping heat over a 100-year period. In 2017, the Earth's atmosphere absorbed nearly

EMISSIONS LAG

It could take decades for even big reductions in greenhouse gas emissions to lead to detectable changes in global surface temperatures, a new study in *Nature Communications* has found.

Even fully removing emissions of short-lived climate forcers like black carbon would not be discernible for a decade. The findings emphasise the need for long-term commitment, the authors say.

"The study reinforces our understanding that climate change is a long-term problem that will not simply disappear if all human-related emissions stopped tomorrow," said Grant Allen, professor of atmospheric physics at the University of Manchester.

600 million tons of methane, a 9 per cent rise since the early 2000s, with more than half of all emissions coming from human activities such as the burning of fossil fuels and agriculture. In terms of warming potential, adding this much extra methane to the atmosphere since 2000 is akin to putting 350 million more cars on the world's roads, the researchers say.

"We still haven't turned the corner on methane," said Rob Jackson, professor of Earth system science in Stanford's School of Earth, Energy & Environmental Sciences (Stanford Earth). "Emissions from cattle and other ruminants are almost as large as those from the fossil fuel industry for methane. People joke about burping cows without realising how big the source really is."

Livestock farming and emissions from cows are a driving factor in methane increase

"In 2017, the Earth's atmosphere absorbed nearly 600 million tons of methane"

According to the researchers, curbing methane emissions will require reducing fossil fuel use and controlling errant emissions such as leaks from pipelines and wells, as well as changes to the way we feed cattle, grow rice and eat.

"We'll need to eat less meat and reduce emissions associated with cattle and rice farming, and replace oil and natural gas in our cars and homes," Jackson said.

INSPIRED EXPIRED

CARBON SOLUTION

Restoring the UK's peatland, coastal marsh and other degraded natural habitats could absorb a third of the country's CO_2 emissions, a report says.

LOW-CARBON RIDE

Replacing petrol ride-hailing taxis with electric vehicles reduces emissions three times more than replacing private petrol vehicles with electric ones, a California-based study has found.

COCO HAZARD

Coconut oil threatens more species per metric tonne produced than palm, olive and soybean oil. This is because it's largely grown on tropical islands with many unique species, a study says.

ARCTIC SPILL

Rising shipping in the Arctic could pose risks to human safety and environmental security including oil spills, says a new report to the Nordic Council.

IT'S EASY BEING GREEN

THINK ABOUT YOUR MILK

Understanding which kind of milk is best for the planet can be a tricky balancing act, but fortunately, there is some useful data to guide us. Cow's milk has by far the highest carbon emissions and water use of five types of milk examined by a team at Oxford University in 2018. The production of cow's milk also requires at least 11 times more land than the others. Of the milk alternatives, rice milk has the highest carbon footprint, while almond milk has the lowest. However, almond milk does use a lot of water. Soy and oat milk are slightly higher in carbon emissions than almond milk but use far less water.

GETTY IMAGES X4, ALAMY X2

Dr Rachel Brown MRC clinical training fellow

Horizons

COVID-19 could cause delirium, brain inflammation and stroke

A study carried out on a small number of confirmed or suspected COVID-19 patients at the National Hospital for Neurology and Neurosurgery has linked the coronavirus to a number of neurological conditions

CAN YOU TELL US ABOUT YOUR RESEARCH?

COVID-19 is still predominantly a respiratory illness, but in a small subset of patients we've been seeing neurological symptoms and syndromes. Some of the early studies from Wuhan showed that around a third of patients were having neurological symptoms. In those early descriptions a lot of the symptoms that people were describing included things like headache and dizziness, loss of smell and things that could just really be attributed to viral illness. As we gained more experience, we noticed other cases appearing that looked a little bit different. We have information from other viral illnesses, SARS and MERS and things like that, so it wasn't unexpected that neurological symptoms or syndromes might come out of COVID-19 as well.

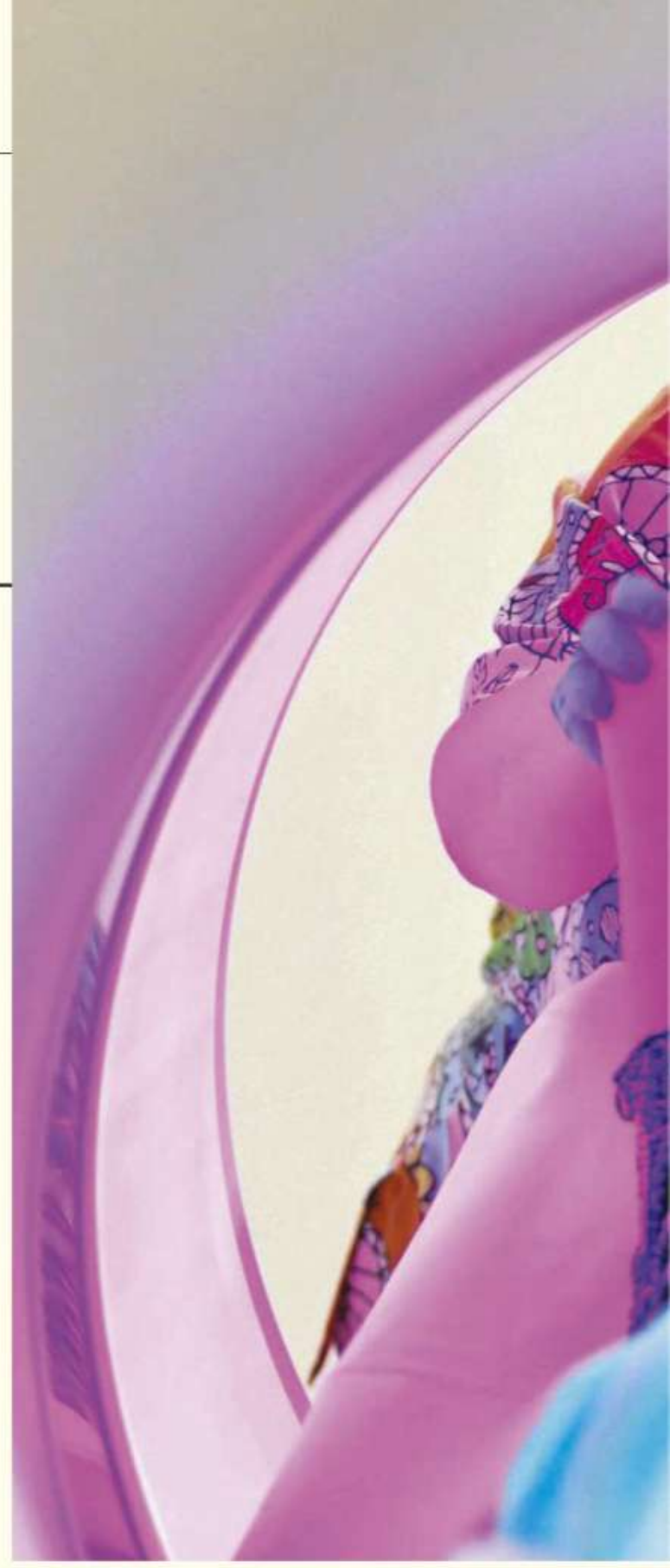
At our centre, which is a specialist neuroscience centre linked with lots of different hospitals and centres across London and the UK, we already had a multidisciplinary platform for discussing inflammatory and infectious diseases. When COVID-19 came, we set up a weekly meeting open to colleagues across London. By doing that we were able to pool experiences as it [the disease] was coming through. That was really important, that collaborative effort, because these complications are on the rare end of the spectrum. It allowed us to spot patterns in what we were seeing. The sorts of things we were seeing were encephalopathy, which is a transient brain dysfunction; a delirium-type condition, which can be very common in infections and with hospital admission generally; and we were also seeing patients with post-infectious problems with the brain or the nerves – this ADEM-like [acute disseminated encephalomyelitis] illness and also some patients who had Guillain-Barre syndrome as well. We were also seeing some unusual strokes.

We now know that COVID-19 can make your blood sticky. In some patients, that can lead to development of stroke, even in those where there aren't traditional risk factors.

WHAT ARE THE EFFECTS OF ADEM AND GUILLAIN-BARRE SYNDROME?

They're both what we call para- or post-infectious inflammatory syndromes, affecting the nervous system. ADEM affects the brain and the spinal cord, usually after an infection, and is usually most common in children and adolescents. Patients can get headaches, they can be drowsy, they can have weakness, sometimes seizures. But it tends to be a one-off illness with recovery afterwards.

Guillain-Barre is similar in that it's also a post-infectious inflammatory



GETTY IMAGES

"When these complications happen, they can be very severe, so it is important that we know about them"

A member of medical staff prepares a patient for a CT scan

syndrome, but it affects the peripheral nerves supplying movement and sensation to the arms and legs. It's thought to be an immune cross-reaction, where the immune system mistakes certain proteins or cells in our body for viruses, and can lead to inflammation.

HOW COMMON ARE THESE NEUROLOGICAL COMPLICATIONS LIKELY TO BE?

On the whole, I think the neurological complications are likely to be rare, and that the complications we are describing are on the more severe end of the spectrum. When these complications do happen, they can be very severe and can be life-changing, so it is important that we know about them, but on the whole they are likely to be rare.

ARE THERE ANY TREATMENTS THAT COULD LOWER THE RISK OF THESE NEUROLOGICAL COMPLICATIONS IN PATIENTS WHO ARE HOSPITALISED WITH COVID-19?

What we don't know at the moment is exactly what is driving each of these conditions. We know that ADEM and Guillain-Barre are usually post- or para-infectious auto-inflammatory illnesses, but some of the cases were a little bit more unusual. We described some of the ADEM cases as 'ADEM-like' and saw small areas of microhaemorrhage [bleeding] more than we would expect. The delirium cases could have a range of underlying causes. For the stroke cases, the prothrombotic [abnormal blood clotting] effect that COVID-19 can trigger may be having an impact.

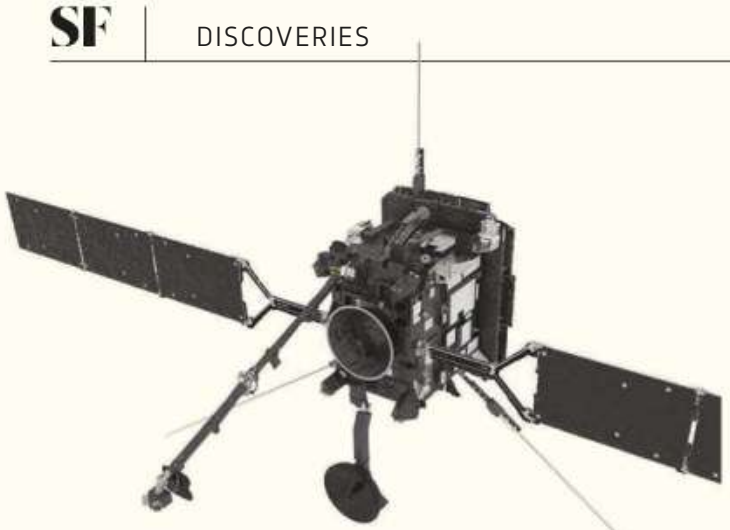
There are probably a number of different mechanisms underlying the different neurological syndromes that we're seeing. One thought is whether the virus itself is doing some of this, but we don't actually have a lot of good evidence, and few reports have actually found the virus in the brain or in the spinal fluid. So that's either related to the way we were looking for the virus or testing for it. Maybe our tests aren't sensitive enough, or maybe it's actually that there are other things that are underlying these conditions. The immune system is probably going to be a major factor for a number of these complications, but there also might be other factors. For example, some patients can become very hypoxic – that's low oxygen levels – we know that that can affect the brain and the nerves. For others there may be a contributory effect of a prolonged or severe illness, including admission to the ICU.

WHAT ARE THE NEXT STEPS?

What's been really exciting is just how much the medical community has mobilised and come together. My colleagues across the UK and the world will be trying to understand each of these conditions better, to find out exactly what is driving each one. We need to look at each category. We need to see how frequently this is actually occurring and how many people it's affecting. Is it the virus itself or the illness that is triggering it? What are the underlying mechanisms? We need to identify which patients are most at risk so that we can try and reduce the risk of these neurological complications happening, and then we need to look at how we're going to treat each one.

DR RACHEL BROWN

Rachel is an MRC clinical research training fellow affiliated to the UCL Queen Square Institute of Neurology and the UCL Institute of Immunity and Transplantation. ***Interviewed by*** **BBC Science Focus** ***commissioning editor Jason Goodyer.***



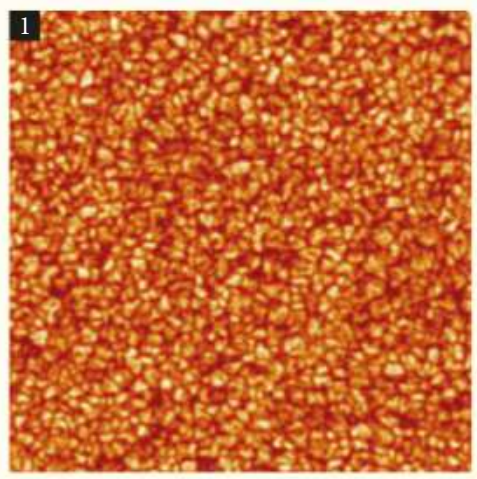
Solar Orbiter

SOLAR SYSTEM

Solar Orbiter captures closest-ever pictures of the Sun

ESA's Solar Orbiter probe photographs our star from a distance of just 77,000,000km

In February this year, the Solar Orbiter craft was launched aboard an Atlas V rocket from Cape Canaveral, Florida. With six remote-sensing telescopes and four in-situ instruments, the probe is on a mission to image and monitor the Sun and its surrounding environment. Led by the European Space Agency (ESA) and aided by NASA, the project soon encountered a number of challenges due to the coronavirus pandemic. However, in mid-June the team announced that the probe was ready to start performing science, and it's already delivering the goods. In mid-July, ESA released this set of images from a distance of 77 million kilometres from the Sun – the closest-ever photographs of our star. The probe is now in its cruise phase and will continue travelling towards the Sun. In late 2021, it will get as close as 42 million kilometres, when the main part of the mission will proceed.



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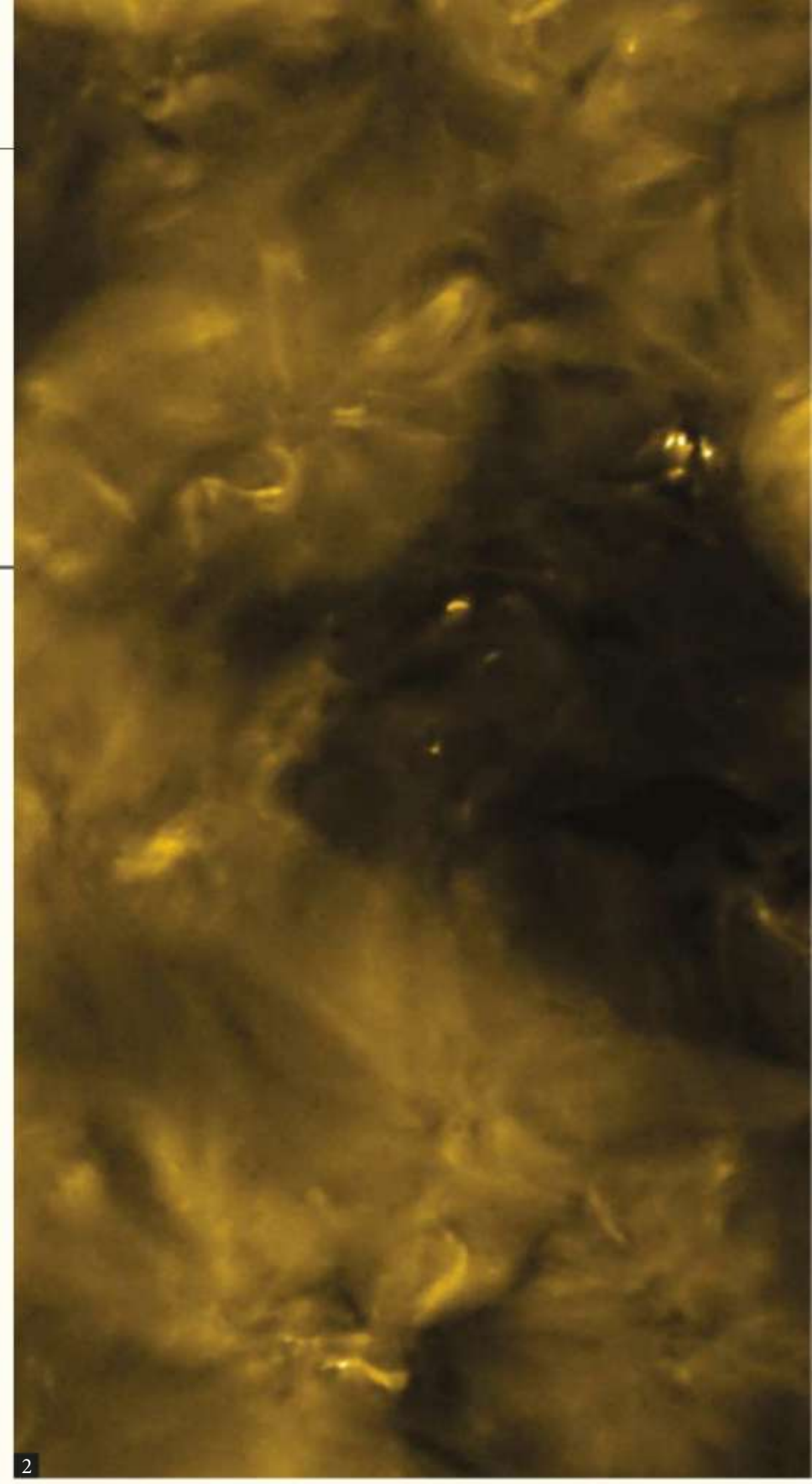

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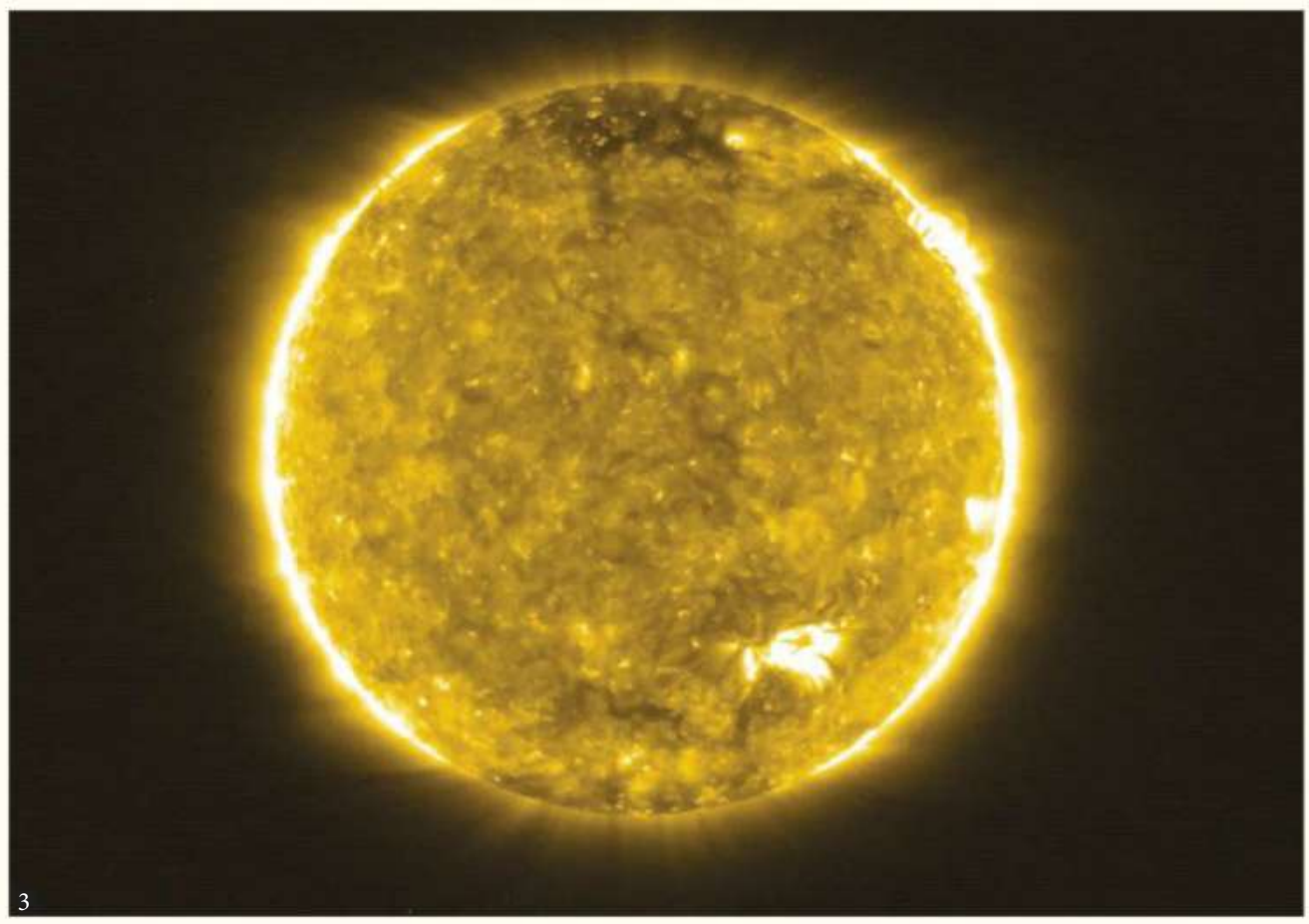

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ESA/NASA/PHI TEAM X6

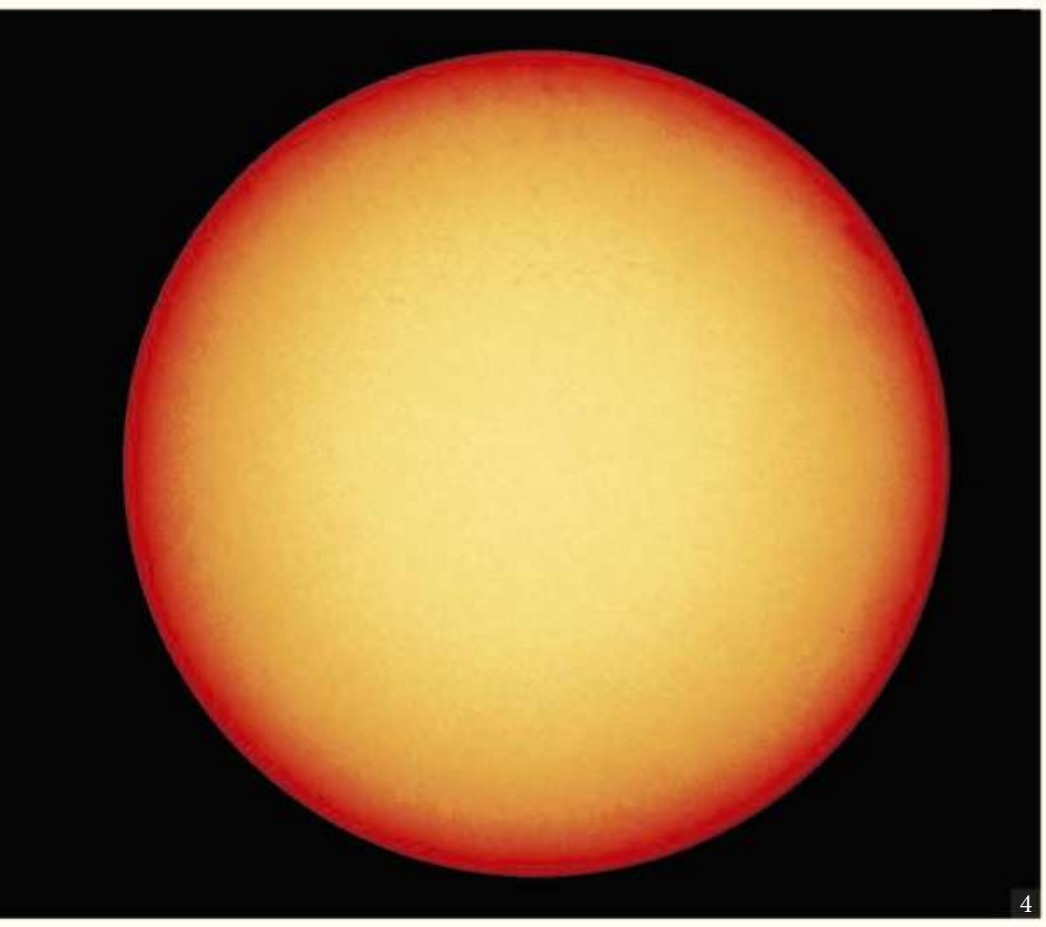
1. The Sun's 'granulation pattern', caused by hot plasma moving under its surface. This was taken with the Polarimetric and Helioseismic Imager (PHI)

2. The Sun, photographed by the Extreme Ultraviolet Imager (EUI). Snapshots taken at these wavelengths reveal the Sun's upper atmosphere, the corona

3. A full view of the Sun, taken with the EUI. The corona has a temperature of 1,000,000°C

4. The PHI took this visible light image of the Sun, representing as we would see it with the naked eye

5. The corona, taken with the Metis instrument. This blocks out the Sun's light, to allow the corona to be imaged. Two bright 'equatorial streamers' can be seen on either side



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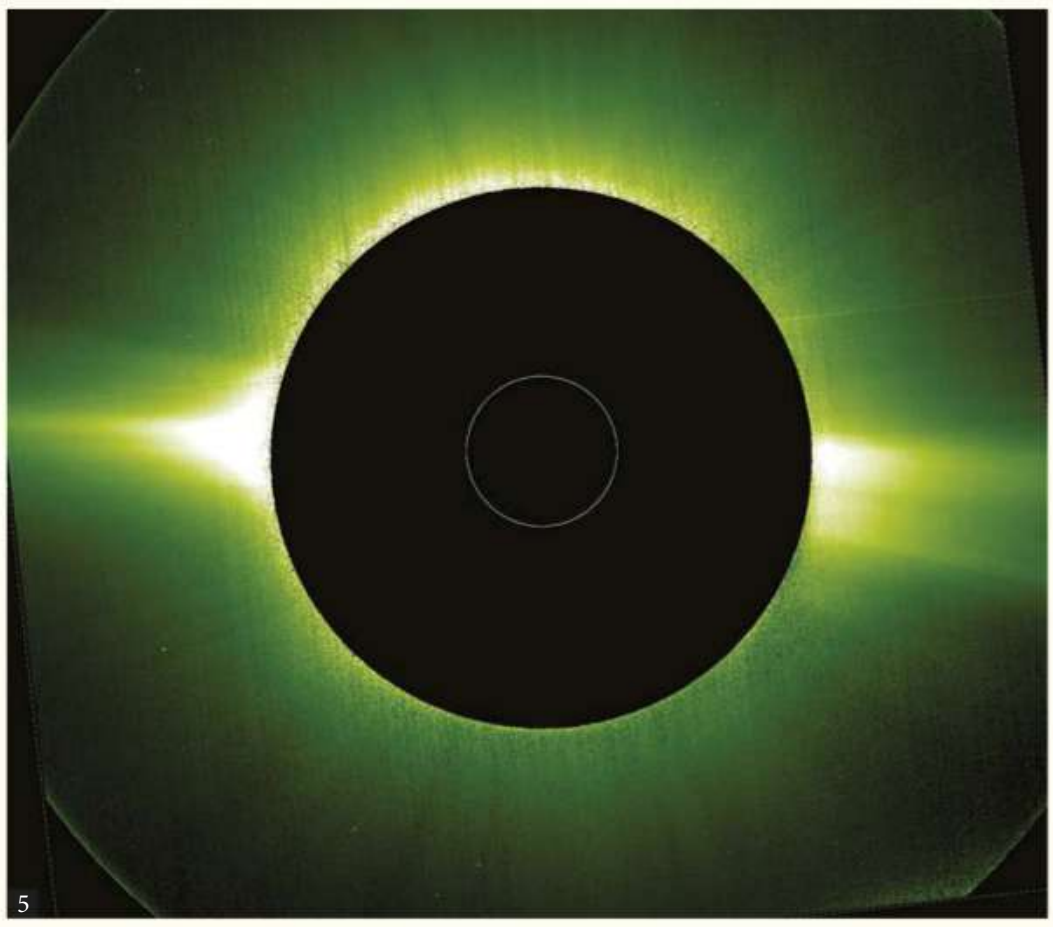

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SCIENCE BEHIND THE HEADLINES

Airborne transmission | Treating COVID-19 | Statues and psychology

REVIEW

CORONAVIRUS: IS IT AIRBORNE?

There are growing claims that the virus can drift in the air and infect people over longer distances. What's the evidence?

"The researchers calculated that one minute of loud speech could generate at least 1,000 small, virus-containing droplets"

BBC

Visit the BBC's Reality Check *website at* ***bit.ly/reality_check_*** *or follow them on Twitter* ***@BBCRealityCheck***

WHAT'S THE MAIN WAY THE CORONAVIRUS SPREADS?

The scientific consensus is that the coronavirus is spread mostly through 'respiratory droplets': virus-laden globs of saliva or mucus that are propelled from an infected person's nose or mouth when they cough, sneeze, talk or sing. These droplets are larger than five micrometres (µm) in diameter (one micrometre = one-thousandth of a millimetre), and don't tend to travel more than one to two metres before succumbing to gravity and landing on a surface. If someone else is close by, the droplets can enter their nose, mouth or eyes directly. The droplets can also be picked up indirectly via a contaminated surface such as a door handle or shopping basket. This is why we're all told to practise physical distancing and regularly wash our hands.

WHAT IS AIRBORNE TRANSMISSION?

When we breathe, talk, cough, and so on, we also produce smaller droplets of mucus and saliva. Droplets with a diameter of less than around 5µm are small enough to be suspended in the air (becoming what are known as 'aerosols'), where they can remain for minutes or even hours, potentially travelling much further than the larger droplets. Measles is an example of a disease that's transmitted mostly via smaller droplets.

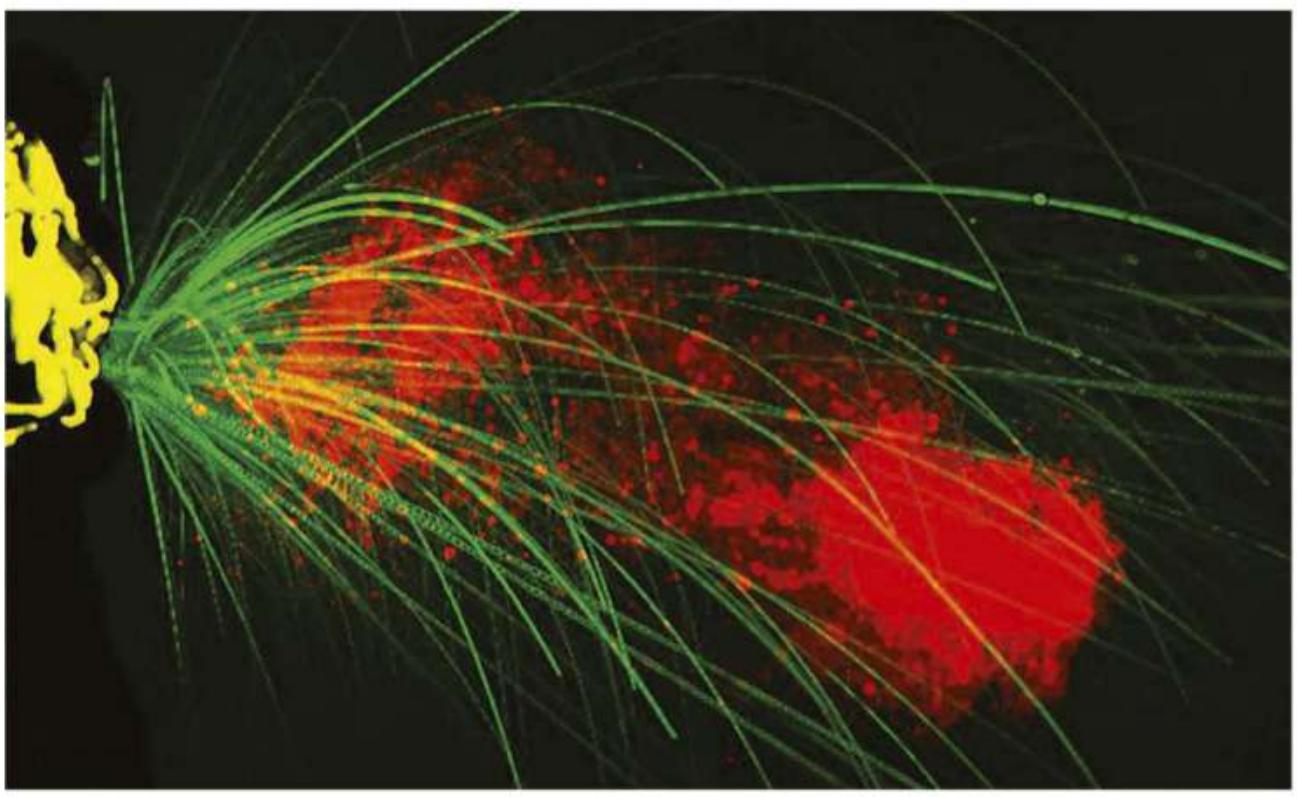
CAN THE CORONAVIRUS BE TRANSMITTED IN THIS WAY?

Scientists are pursuing a few lines of possible evidence. First, lab studies. One recent study used laser light scattering to detect the droplets fired out as a participant talked. The researchers calculated that one minute of loud speech could generate at least 1,000 small, virus-containing droplets, which could remain in the air for eight minutes or more. Other scientists have created virus-laden aerosols using a device called a nebuliser, with one study finding that the virus in these droplets was still infectious after 16 hours. However, the World Health Organization notes that artificially-created aerosols such as these "do not reflect normal human cough conditions".

Other studies have analysed air samples to look for the virus in the real world. One study in Wuhan, the city where the pandemic began, found the virus's genetic material in air samples from two hospitals, although the researchers say that they don't know whether the virus was still infectious.

Finally, researchers have highlighted specific events where airborne transmission may have played a role. One such event involved a coronavirus outbreak in early 2020 in Guangzhou, China, when 10 people from three different families became infected. Scientists traced the outbreak to a restaurant in which all three families had eaten lunch on Chinese New Year's Eve. There was no close contact between the families, but they were all sitting in the airflow created by the restaurant's air conditioning system, leading the researchers to conclude that airborne transmission may have been responsible.

On 6 July, over 200 scientists signed a comment piece in the journal *Clinical Infectious Diseases*, urging medics and public health bodies to recognise the ➤



GGETTY IMAGES, LYDIA BOUROUIBA/MIT

BELOW Larger droplets (green) from coughs and sneezes only travel one or two metres, but clouds of smaller droplets (red) can stay suspended for longer, potentially travelling further than the larger droplets

risk of airborne transmission. A few days later, the World Health Organization updated its guidance on how the virus can spread, stating that airborne transmission could potentially occur in indoor, crowded, poorly ventilated settings, and that more research was "urgently needed".

HOW BIG A ROLE DOES AIRBORNE TRANSMISSION PLAY?

That's the big question, says Dr Hassan Vally, an epidemiologist and infectious disease expert at La Trobe University in Melbourne, Australia. "This route of transmission is clearly possible, but we don't know what percentage of new cases it accounts for."

Vally also mentions two more unknowns about airborne transmission: how long the virus can survive inside the smaller droplets, and how many of these droplets you'd need to be exposed to in order to contract COVID-19.

"But regardless of what new evidence comes to light, I don't think it's going to change the fact that the predominant route of transmission is the larger droplets," he says. He also points to the fact that social distancing has been largely effective at halting the virus's spread, which is "further evidence that people are most often getting the disease from close contact with other people".

IF THE VIRUS IS FOUND TO BE AIRBORNE, WILL PUBLIC HEALTH ADVICE BE CHANGED?

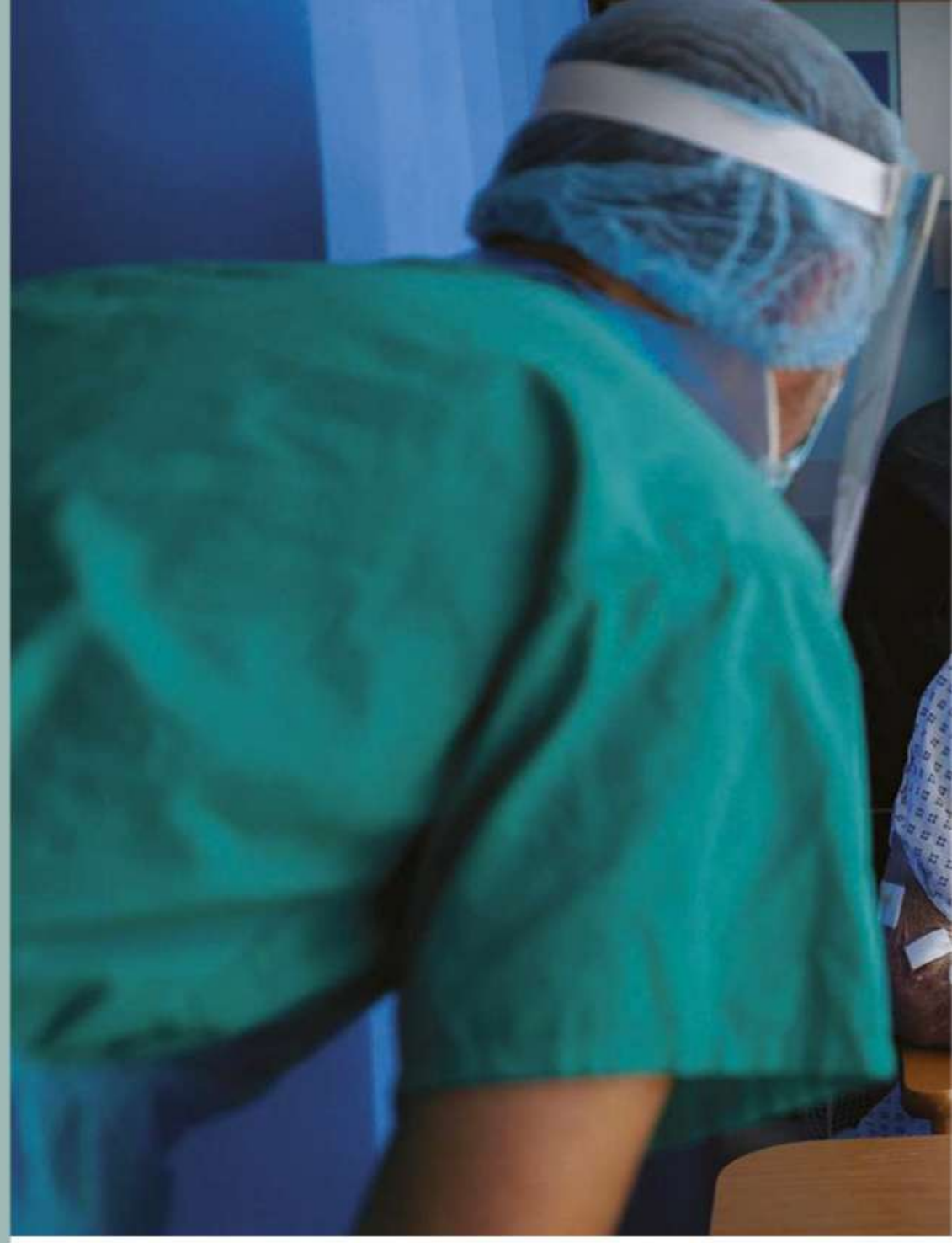
If the virus does have the potential to become airborne and stay infectious in the smaller droplets, it would mean that people are more likely to become infected without close contact. But Vally doesn't think that this would lead to an overhaul of public health policies. "It would probably just mean that we encourage more mask use, to stop the droplets reaching us," he says.

Another way to reduce airborne transmission would be to ensure that enclosed spaces are ventilated with clean outdoor air, rather than just recirculating the same air. "And there might be things we can do to reduce the virus's chance of surviving in aerosols," says Vally, "perhaps by altering the [building's] temperature or humidity.

"I don't think it's going to be a game-changer," he says. "It's just another thing to learn about what is a very complex virus."

by **JAMES LLOYD**

James is the staff writer at BBC Science Focus.



ANALYSIS

COVID-19: HAVE WE BEEN TREATING IT WRONGLY?

As more symptoms are confirmed, it becomes clearer that COVID-19 is not a normal respiratory infection. Should we approach its treatment differently?

Back in January, when the coronavirus was very new and still confined to Wuhan, we were working on the assumption that COVID-19 was more or less an ordinary respiratory disease. The World Health Organization described the symptoms as "mainly fever, with a few cases having difficulty in breathing", with some patients developing pneumonia.

Even on 31 January when the UK's first cases were confirmed, Prof Chris Whitty, the chief medical officer for England, described COVID-19 as a "relatively minor disease" for most people, going on to say that those who were most seriously affected would be treated "as anyone else with a respiratory disease". As time went on, however, more and more symptoms were added to the list.

ABOVE COVID-19 is not as simple an illness as first thought

GETTY IMAGES

"People have a very large number of different symptoms and many of those symptoms aren't immediately obviously related to infection," says Dr Ajay Shah, professor of cardiology at King's College London. "People with diarrhoea. People come in with confusion. People come in with chest pain."

The list goes on. Some patients report rashes like 'COVID toe', which appears on the feet. And even if the cough and fever clear up, patients can end up suffering a heart attack, stroke, or kidney failure. In fact, one study found that heart problems played a role in 40 per cent of COVID-19 deaths.

So how could a flu-like illness cause all of these different symptoms? "I guess the starting point is it's definitely not a simple infection," says Shah. "You might think maybe people who've had chest problems like chronic obstructive pulmonary disease or asthma are more likely to get [severe COVID-19]. But actually, you are much more likely to get nasty COVID if you have pre-existing cardiovascular conditions."

It turns out that COVID-19 affects the endothelium, which is the layer of cells that lines the inside of blood vessels, as described in a paper published in the journal *The Lancet*, hinting at how COVID-19 could affect the entire body. "The virus actually uses a particular receptor on the endothelial cells," says Dr Nicola Mutch, a molecular biologist at the University of Aberdeen. Once it's attached to this receptor, SARS-CoV-2 finds its way inside the endothelial cell, and from there, causes a huge inflammatory immune response called a 'cytokine storm'. "All of us need to have an inflammatory response to tackle an infection. But for most of us, it's properly tuned," says Shah. While it's not yet clear why the immune response differs from patient to patient, an overactive inflammatory response causes more problems than it solves, potentially leading to organ failure and even death. "It seems that in people with COVID, this is a very, very important part of why people end up needing hospital," he adds.

Shah believes that the progression of severe COVID-19 can be broken down into stages. The first one is this exaggerated inflammation, the cytokine storm. The second is a problem with blood clotting, known as coagulopathy. "Very early on when we started seeing the patients, we noticed that a lot of patients were developing clots everywhere," Shah explains. "Getting clots in the lungs. Some patients are getting clots in their hearts. Some people are getting clots in the brain."

A study published in the journal *Thrombosis Research* confirmed that blood clots were linked to an increased risk of death in COVID-19 patients. This could explain many of the complications of COVID-19. "If you have this kind of systemic coagulopathy – a systemic problem with clotting – then it's very easy to imagine how the disease kind of goes out of control and begins to affect lots of different parts of the body," Shah says. Strokes and organ failure, for example, can both happen as a result of a clot preventing blood flow.

Luckily, this means we already have plenty of ready-made treatments that can be applied to COVID-19. "We're fortunate that we do have a number of anti-coagulant drugs that have previously had some success," says Mutch. "We're always looking for new anti-coagulant drugs, to be honest."

We could even go back a step and treat the inflammation. "Treating the inflammatory response to stop the thrombosis [blood clot formation] is also another possibility," Mutch explains. The low-cost steroid dexamethasone, is one possible treatment: in June, it was shown to reduce deaths among patients on ventilators by up to a third.

"I think possibly the most important take-home message would be that it's a very complicated disease, which is not the same for everybody," says Shah. "We probably need to look much more carefully at the individual patient and then decide what's the best treatment for that particular patient."

—

by **SARA RIGBY**

Sara is online assistant at BBC Science Focus.

COMMENT

PUBLIC MEMORIALS: CAN REMOVING THEM AFFECT OUR NATIONAL PSYCHOLOGY?

As the world debates what we should do with certain memorials and statues, what can the study of social psychology and neuroscience tell us about how the brain responds to these monuments?

Statues and sculptures have always been used to convey information and ideas. They have formed a part of our cultural sensibilities and urban design for as long as we remember, but there are always periods in history when these become more prominent than others.

Public memorials are erected to mark regeneration and rejuvenation of a city or a country, and to celebrate heroes who we believe have been instrumental in shaping our collective national identity. The foundation for a unique nationalistic identity, and crucial to people's sense of belonging, is collective memory. The notion of collective memory was first postulated by French philosopher Maurice Halbwachs. Halbwachs asserted that it is in society that we acquire most of our memories, that there exists a collective memory, and "it is to the degree that our individual thought… participates in this [collective] memory that it is capable of the act of recollection."

Political power is often legitimised by the galvanisation of this nationalistic narrative, often by simplifying history and condensing it into a few iconic milestones, events and people, to form the backbone of the collective past.

The notion of nationality is intricately linked to identity and belonging, and to race. These associations emerge early in life and are shaped by cultural context: the messages we get around us create implicit biases.

These cues from our environment are not benign. Neuroscience research has shown that dopamine neurons are one way that our brains give things around us meaning. Dopamine neurons get activated in the presence of rewards such as food and water, but they can also imbue environmental cues, such as signs and landmarks, with value and meaning. This gives them the ability to drive behaviours and motivate actions.

We are constantly engaging with the statues around us in our environment, and these affect not only the way we see our past and our history, but also our emotions, and how we feel and act.

"We are constantly engaging with the statues around us in our environment, and these affect not only the way we see our past and our history, but also our emotions, and how we feel and act"

REINTERPRETATION OR REMOVAL?

Discussions surrounding statues and sculptures are fraught with complexity and charged with emotion.

The American Museum of Natural History (AMNH) in New York addressed the racist views and actions of 20th-Century US President Theodore Roosevelt, whose father was one of the founders of the museum, with an exhibition in 2019. The *Addressing the Statue* exhibit explored the museum's design and installation, as well as Roosevelt's racism. The museum also took other actions, such as adding detailed captions to artefacts to address past errors.

Then, in June 2020, the AMNH made a statement that the statue of Roosevelt in its entrance "should no longer remain and have requested that it be moved".

GETTY IMAGES

ABOVE In June 2020, the statue of Edward Colston was pulled down during protests in Bristol

Other possible solutions were proposed by conservationists around the world, including the suggestion to add to the monument in a way that recontextualises it. Neither of these solutions are optimal.

AVAILABILITY BIAS

While reinterpretation might provide added context to help change the meaning of monuments, it will not happen instantly. The visual image is often much stronger than words, and any reimagining of our history that leaves some of the contentious past edifices intact does not address the problem of availability bias.

When we see something every day, we are more likely to believe its narrative. This cognitive shortcut operates on the notion that if something can be recalled, it must be important, or at least more important than alternative solutions that are not as readily recalled. Availability of information is correlated with environmental frequency, and so anything that exists more often is more easily recalled. No amount of interpretation will change the ease of recall associated with these exemplars.

Statues and monuments are triggers for our collective memory, set in stone. These, along with the history we are taught, all reinforce power structures in society about whose history is important and who should be able to tell it. But history is never set in stone: the past is. History is merely a representation of the past that is inevitably determined by those with power. There is, and always has been, a power imbalance in how history is written and told, and whose history gets recorded.

As we debate the falling and removal of statues around us, we might wonder if it is erasing our past, and destabilising our collective identities. But, history has always been revised and rewritten. Our collective and individual identities shift and acquire different meanings over time.

As we discuss whether these controversial statues should go or stay, those making decisions should consider the impact these cues are having. As statues are examined for the roles they play in shaping our identity and sense of belonging, it is also important to consider what views and narratives of history are embodied in these different monuments, and who should decide whether these are preserved or destroyed. **SF**

—

by **DR PRAGYA AGARWAL**

Pragya is a behavioural and data scientist, and author of the bestselling book Sway: Unravelling Unconscious Bias *(£16.99, Bloomsbury Sigma).*

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INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

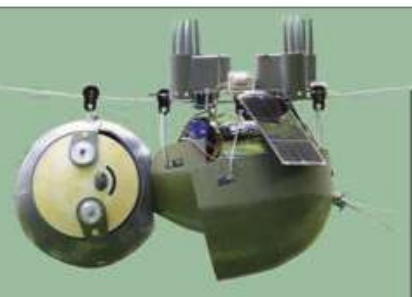
The KUKA robot saves lab staff from carrying out tedious and time-consuming experiments

MORE ROBOT HELPERS

SoFi Robotic Fish

A team at the Massachusetts Institute of Technology built a robot that mimics the movements of real fish, swimming alongside marine animals to give researchers an eye under the sea.

SlothBot



Named for its slow pace, low energy requirements and position in the trees, the SlothBot aids conservation research by monitoring animals and plants in the Atlanta Botanical Garden.

Spot

The Spot robot can be found down mines, on construction sites, in healthcare, and even performing with Cirque du Soleil. Nimble, adaptable, autonomous: it's a researcher's best friend.

ROBOTS

Meet the robot that's tackling chemistry's biggest challenges

This robot chemist took eight days to discover a new catalyst – a task that would've taken human researchers months to complete

When a team at the University of Liverpool set out to find a new chemical catalyst that could speed up the extraction of hydrogen from water – an area of research that has implications for green energy and other industries – they knew they were looking at a lot of work. There were millions of possible experiments to run in their search, so they wanted to find an alternative way of doing things. And what could be better than a robot chemist?

"Our motivation was to make what is a complex process autonomous," explains Prof Andrew Cooper, who led the development of the robot chemist.

The robot was created from a KUKA Mobile Robot. It has access to a map of the laboratory to allow it to move through the space safely, and its speed is capped at 0.5 metres per second. To navigate, it uses a combination of laser scanning – similar to the LIDAR system used by driverless cars – and touch-feedback, meaning it can operate in the dark. In fact, the robot can work seven days a week for 21.5 hours a day, only pausing to charge its battery.

"IT TAKES ONE DAY TO SET UP THE ROBOT, AND IT CAN THEN DO 1,000 EXPERIMENTS BY ITSELF"

While the robot's arm can carry up to 14kg, the catalyst experiments used much lighter equipment. "A rack of filled vials has a mass of 580g," write the researchers in the paper, "but [the payload capacity] could allow for manipulations such as opening and closing the doors of certain equipment."

After being set basic parameters by the researchers, the robot was left to choose between the 98 million possible candidate experiments, choosing which ones to carry out based on the results of the previous ones. In just eight days it completed 688 different experiments, and found new photocatalyst mixtures that were six times more active than the scientists' initial formulations.

"Previously, we were doing one photocatalysis experiment per day, by hand," says Cooper. "Now, it takes one day to set up the robot, and it can then do 1,000 experiments by itself – or conceivably more if we gave it more consumables."

Its human-sized dimensions mean it can fit into pre-existing lab spaces without the need for lowering desks or adjusting equipment, but the researchers have not designed the robot to replace real scientists. Instead, Cooper says humans and robots can collaborate on tasks, particularly when automating an entire production process would be too expensive.

A robot chemist is no cheaper than a salaried human, either. "Mobile robots of this kind cost between £50,000 and £150,000, depending on their capabilities," says Cooper. "This might sound expensive, but for context, the gas chromatograph – a common instrument in chemistry research used to measure hydrogen production – falls in the same range. It is also not uncommon for chemistry labs to have equipment that costs upwards of £500,000."

Cooper's next step is to make the robot smarter. "In the example we published, the robot has no concept of what the chemistry is – it could equally be baking the perfect cake. In the future, we want to put a chemical brain in the robot. That is, so that it can make decisions that are based on the chemical inputs as well as the measurement outputs."

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ON TEST

Wireless wonders

The shops are flooded with a tide of earbuds that have broken free from their cables. Mike Sawh finds the ones that rise to the surface...

Sennheiser Momentum True Wireless 2

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As has become the earbuds norm, Sennheiser gives you quick access to Google and Apple's smart assistants, while the charging case provides half a day's worth of extra listening time.

PRICE: £279
BATTERY LIFE: Four hours off a single charge
COMPATIBILITY: iOS and Android
ACTIVE NOISE CANCELLATION: Yes
en-uk.sennheiser.com

Apple AirPods Pro

It's taken Apple a couple of iterations to deliver a pair of wireless earbuds that justify the hefty price tag. The AirPods are still all-white, but a smarter, stubbier design means that you no longer look like you've stuck a pair of electric toothbrush heads in your ears.

Unsurprisingly, the AirPods play best with Apple hardware, with a setup that's mercifully painless thanks to the new chip technology.

Sound quality has stepped up a notch, offering something that's more balanced. It's not heavy-handed with the bass and there's a nicer sense of detail. The headline grabber is the addition of active noise cancellation, to help drown out the world. Apple uses outward microphones to detect the noise from outside, and an inward-facing one to deal with sound that makes it through the seal.

There's even room to squeeze controls into the stem, while a pocket-friendly case gives them a quick battery boost. More features are on the way too, including surround sound support and a smart switching mode that pairs to the device you're currently using.

PRICE: £249
BATTERY LIFE: 4.5 hours off a single charge
COMPATIBILITY: iOS
ACTIVE NOISE CANCELLATION: Yes
apple.com/uk

Jabra Elite Active 75t

Jabra's heritage lies in headsets, the kind you'd find littering office cubicles. These days, it also knows a thing or two about making earbuds that you can use for longer than most of its closest rivals.

The 75t sits more discreetly than most earbuds and delivers a powerful audio roar with satisfying clarity. Perform the hearing test in Jabra's smartphone app and you can get sound more tailored to your ears. Take things further and pick from preset sound profiles, or create your own to make things sound even more personal. It's one of the few options that gives you hands-free access to Amazon's Alexa, while its waterproof and sweatproof ratings improve the durability stakes.

It delivers big battery life with a speedy 15-minute charge, getting you a useful hour to play with. There's even a version that plays nicely with wireless charging pads, to save you from scrambling for the charging cable.

PRICE: £189.99
BATTERY LIFE: Seven hours off a single charge
COMPATIBILITY: iOS and Android
ACTIVE NOISE CANCELLATION: No
jabra.co.uk

Nuheara IQbuds² MAX

Nuheara isn't a household name in the audio space, but it's taking big strides to build something beyond the typical wireless earbuds. You can perform a clinically validated hearing test to adjust the sound settings, in order to make these buds a better fit for your hearing strengths and weaknesses at different frequencies. This is sound customisation at its most comprehensive, and some audiophiles will no doubt appreciate its thoroughness.

The ability to augment sounds is a big benefit. You can filter out background noise and focus on the sounds that matter most to you, giving them some appeal to those who suffer with mild to moderate hearing loss. Walking around in 'street mode' and hearing the sound of barking dogs, or conversations amplified in greater detail, is pretty impressive.

They sound good too, offering a profile that prioritises clarity over heaving bass, while still offering satisfying warmth. There's proper noise cancellation as well, for when you need to block out your worldly environment.

Nuheara talks of itself as a smart hearing company and the IQbuds² MAX live up to that billing of offering better control over the way you hear the world around you.

PRICE: £314
BATTERY LIFE: Five hours off a single charge
COMPATIBILITY: iOS and Android
ACTIVE NOISE CANCELLATION: Yes
nuheara.com

Ideas we like...

→

Toothbrushes that smile at you

Okay, so we're not totally sold on the idea of a gadget that winks and smiles at you when you put it in your mouth. Clearly Douglas Adams wasn't far off the mark when he predicted doors that would sigh with pleasure when they open. But jokes aside, this toothbrush is crammed with an almost implausible amount of tech. There are different modes (like one for whitening, another for sensitive teeth), 3D tracking of your brushing technique, and alerts when you start scrubbing too hard.

Oral B iO
£TBC, io.oralb.co.uk

↑

Displays made for console gaming

If you end up using your TV for gaming more than, well, watching TV, then you might want to consider one of a new breed of displays built for console gaming. This model from Philips pairs ultra-fast refresh rates (ideal for gaming) with Ultra-HD resolution and multiple HDR modes. Plus, there's a speaker system fitted beneath the display that's built by British hi-fi stalwarts Bowers & Wilkins. There's also Ambiglow tech inside, which projects colours from the picture out of the edges of the display.

Philips 558M1RY
£1,199, philips.co.uk

↘

Recycled wallets

Car windscreens are lined with something called PVB (polyvinyl butyral) which stops the glass shattering into the passenger cabin in a crash. The material makes recycling the glass tricky, but it turns out that if you scrape it off, PVB can form a durable, biodegradable material that can be processed into something resembling leather. Wallet company Ekster has taken 600 windscreens and turned them into 240,000 wallets. Each wallet has a push lever at the base that cascades your cards out of the top, and you can pick up a tracker card that pings your phone with the last place you left your wallet.

Ekster Recycled Collection
$99 (£79 approx), ekster.com

← Nissan's second electric car

Just over a decade ago Nissan was one of the first manufacturers to popularise electric cars with the Leaf. Now they have an all-new second model on its way called the ARIYA, which looks to be a big technological leap ahead of the Leaf. It's said to offer nearly 500km (310 miles) of range, a four-wheel drive system modelled on the sporty Skyline, and fast charging when plugged into the right system. The car isn't fully autonomous yet, though it can handle motorways. Down the line, Nissan hopes to introduce automated overtaking, lane diversions and a piloted exit from the motorway. We can't wait to get behind the wheel.
Nissan ARIYA
£TBC, nissan.co.uk

↓ A smart crib that lends a hand

This bassinet and baby monitor combo looks for signs that your precious bundle is about to wake up by monitoring movement, startle reflexes and blinking. Before your baby turns into an air raid siren, the cradle starts rocking to help them drift back off, while deploying soothing sounds. The built-in monitor learns their sleeping habits over time, and provides capabilities like app messages, sleep tracking, and remote view.
Cradlewise
$999 (£795), cradlewise.com

↓ Personalised bikes

Send Superstrata your dimensions, riding style and preferences, and they'll 3D print you a carbon fibre bike frame made to fit. Prefer a stiffer ride? A bike for commuting? Something for touring? Superstrata claims to have over 500,000 possible combinations. There are two versions available: the traditional Terra bike and the Ion e-bike. The Ion has a sleek in-tube battery (no bulky black boxes in sight), takes two hours to charge and lasts for up to 88km (55 miles). Our name is already on the waiting list to receive one when they ship later this year.
Superstrata
From £2,599 for Terra Bicycle; £3,699 for Ion E-Bicycle
superstrata.bike

TO THE ENDS OF THE EARTH

SCIENTISTS ARE GOING TO EXTREME LENGTHS TO FIND OUT HOW CLIMATE CHANGE IS AFFECTING OUR PLANET

WORDS: DR HELEN PILCHER

ROBERT ORMEROD/GUARDIAN/EYEVINE

BBC iPlayer

Watch *Climate Change: The Facts*, presented by Sir David Attenborough at **bit.ly/climate_change_attenborough**

↑ ↓

FAIRWEATHER FRIENDS

ST HELENA, SOUTH ATLANTIC OCEAN

Every day at 11:15am, a team of meteorologists on the Atlantic island of St Helena release a giant latex weather balloon into the sky (previous page). They wear goggles, flash hoods and overcoats 'just in case', because the balloons are full of highly-explosive hydrogen (this lighter-than-air gas causes the balloon to ascend). As the balloon rises to a height of more than 30km, a mini weather station or 'radiosonde' attached to the balloon's neck sends back second-by-second information on temperature, humidity, wind speed and pressure. St Helena's meteorological station (part of which is seen in the image below, being tended by the station's technical manager Marcos Henry) is one of 190 such stations worldwide monitoring the Earth's upper atmosphere as part of the Global Climate Observing System. Conditions here are tricky: St Helena is buffeted by strong winds, and its remote location 2,000km off Africa's southwest coast means that imported goods are pricey. But stations such as this one are playing a crucial role in monitoring the long-term changes in our climate system.

ROBERT ORMEROD/GUARDIAN/EYEVINE, REUTERS X3

A SLICE OF TIME

GEPATSCHFERNER GLACIER, AUSTRIAN ALPS

The ice hidden inside Austria's mountain glaciers is an irreplaceable archive of local climate data. "There is 6,000 years' worth of information collected in 12 metres of ice," says Dr Andrea Fischer, from the Institute for Interdisciplinary Mountain Research in Innsbruck. "Every year, we lose one metre because of climate change." To preserve this precious legacy, Fischer and her colleagues (above) have been drilling ice cores (left) from the Gepatschferner glacier in the Austrian Alps, and then sending them away for storage and study (bottom left). "It's demanding work," says Fischer. "We have to deal with high elevations and adverse weather. Every one of our team is an experienced mountaineer." The researchers hope to use the cores to glean information about past plant life, precipitation and human activity, as well as the waxing and waning of the glaciers themselves. "If we can understand how the landscape recovered from previous bouts of warming, it should help us to prepare for the future," says Fischer.

GETTY IMAGES, SHUTTERSTOCK

←

ON THE ROCKS

OLIVARES ALFA GLACIER, NEAR SANTIAGO, CHILE

Chile's glaciers are vitally important: millions of people living in and around the country's capital, Santiago, depend on nearby glaciers to provide them with water during times of drought. Now droughts are becoming more common, and the glaciers are melting. Here, glaciologist Dr Gino Casassa (left) and hydroelectrical engineer Diego Gonzalez work at a meteorological monitoring station on the Olivares Alfa glacier, 4,200m above sea level in the Andes Mountains. It's mid-winter and the summit should be covered in snow, but the glacier has receded and the duo are standing on bare rock. As director of the Chilean government's Glaciology and Snow Unit, Casassa is working on an inventory of the country's glaciers, and trying to protect them from environmental damage. It's a race against time. The glaciers are threatened by climate change, drought and mining, and Casassa is concerned that in less than two decades, some of the glaciers will be completely gone.

↑

A HEAD FOR HEIGHTS

SEQUOIA NATIONAL PARK, CALIFORNIA, US

During the 2011-2017 California drought – one of the worst in the state's history – some of America's tallest giant sequoia trees began to lose leaves from their crowns. Armed with long ropes and secure harnesses, Dr Wendy Baxter from the University of California, Santa Cruz (pictured) and colleagues climbed 50 of these trees in the Sequoia National Park to retrieve leaves from the top and find out what was going on. "It was gruelling work," says Baxter. The trees are up to 89 metres tall, and samples have to be collected twice daily over a number of years. "We found that the foliage loss was a good strategy used by these trees to reduce their need for water." So for now, at least, these trees are relatively safe, but Baxter points out that all organisms have their limitations. "These trees require enormous amounts of water," she cautions. "I'm concerned that if we don't address climate change, they may not survive into the distant future."

NASA/JSC, GETTY IMAGES

↑

UNDERWATER NURSERY

MOOREA, SOUTH PACIFIC OCEAN

A diver surveys the coral reef off the island of Moorea in French Polynesia. Last year, these corals suffered a major bleaching event as warming waters prompted them to expel the colourful, nutrient-providing algae that normally live inside them. Some of the coral, however, were unaffected, and marine biologist Dr Laetitia Hédouin from the Centre for Island Research and Environmental Observatory (CRIOBE) in Moorea wants to find out why. Genetic factors are likely to play a role, so scientists led by Hédouin are studying DNA samples collected from these

resilient individuals. In addition, divers break off fragments of the hardiest coral and grow them in underwater coral nurseries (above), where they are compared with other colonies. The aim is to use these to replenish the area's ailing reefs, and to bring isolated healthy corals into close proximity with each other so that they can reproduce and maintain the health of the reef in a warmer world.

GETTY IMAGES, JENNIFER LAVISTA/USGS

↑

SOME LIKE IT HOT

COLORADO PLATEAU, USA

Although we may think of deserts as parched and lifeless, they are home to one of the richest and most underappreciated ecosystems in the world. Biological soil crusts, or 'biocrusts', are a community of lichens, mosses and cyanobacteria that live on the soil surface. Just like plants, biocrusts influence atmospheric carbon dioxide levels via photosynthesis and respiration, yet little is known about their role in climate change. In temperatures of more than 40°C, Dr Sasha Reed from the United States Geological Survey checks over a unique experiment. Once an hour, the lid automatically closes on this small sample of biocrust, and carbon dioxide levels are recorded. There are 60 such plots scattered around the desert of the Colorado Plateau near Moab, Utah, and some of them are also heated using infrared lamps to mimic future climate change scenarios. "To know what these plots are doing every hour for years is just incredible," says Reed.

So far, 15 years' worth of data has been collected, and the results are showing that the biocrusts are struggling as the planet warms, which could have knock-on effects across their desert habitat. **SF**

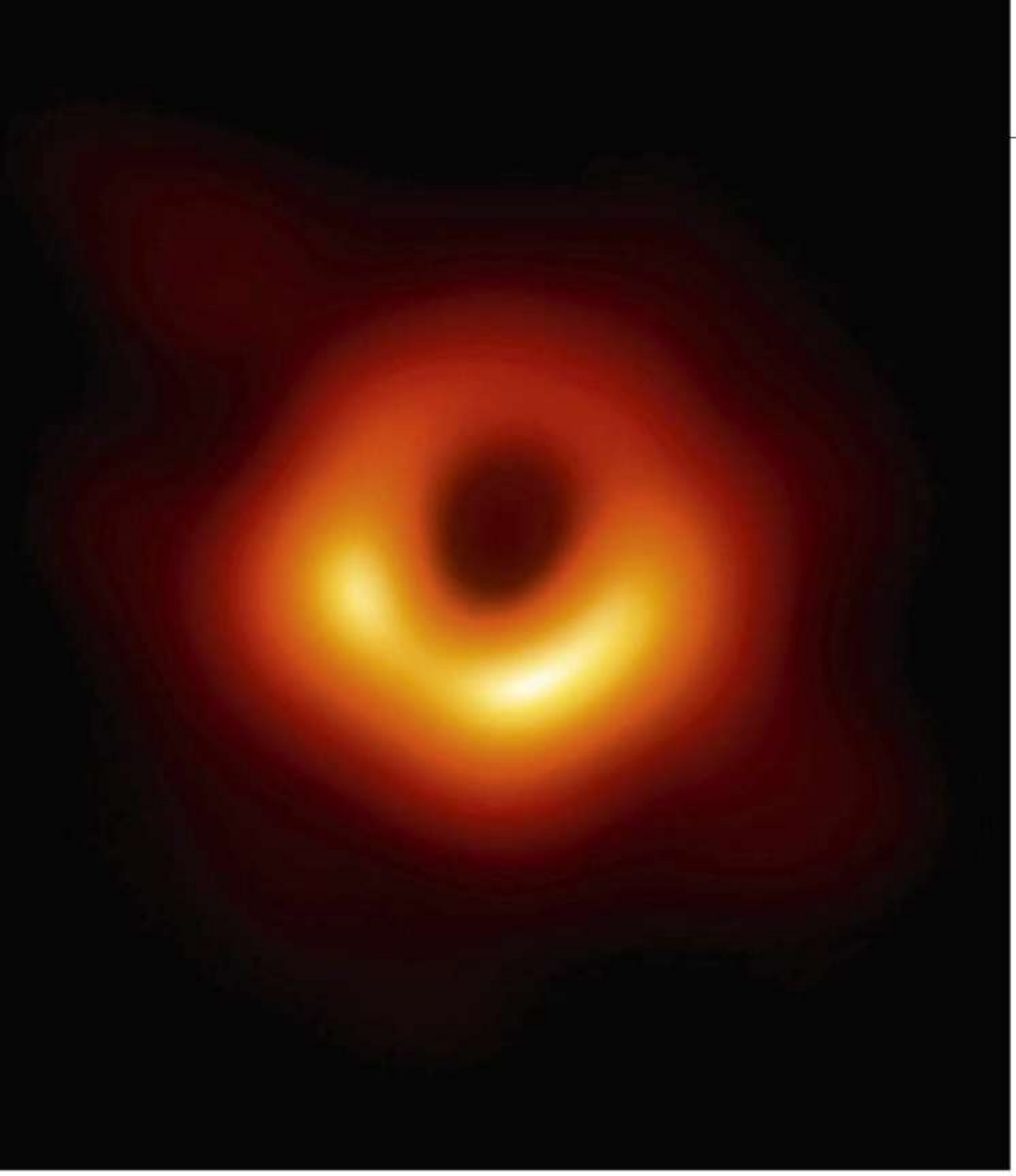
DR HELEN PILCHER *(@HelenPilcher1)*
Helen is an author and science writer. Her latest book, Life Changing: How Humans Are Altering Life on Earth *(£16.99, Bloomsbury Sigma), is out now.*

CAN LIFE EXIST AROUND A BLACK HOLE?

ILLUSTRATION: MAGIC TORCH

Much of the recent search for extraterrestrial life has focused on hunting down planets orbiting in the so-called Goldilocks zone – an area surrounding a star that has just the right conditions for life to emerge. Now, new research suggests that such Goldilocks zones could also exist near supermassive black holes

by **COLIN STUART**



ESO/EHT X2

LEFT The black hole at the centre of the galaxy Messier 87 was successfully photographed in 2019

RIGHT Artist's impression of a top-down view of the accretion disc around Messier 87's black hole

The Earth is in trouble. Dying crops and deadly dust storms are putting the planet under strain, leaving the human race in grave need of a new home. In a desperate attempt to find one, a team of brave astronauts led by Joseph Cooper venture into a wormhole near Saturn, emerging light-years away on Miller's planet – an ocean world orbiting a supermassive black hole known as Gargantua. So goes the plot of the 2014 Hollywood epic *Interstellar*. But according to recent research, this idea might not be as far-fetched as it first appears.

The ability to spot other planets in space has made staggering progress in the last quarter of a century. We now know of more than 4,000 exoplanets – worlds beyond our Solar System orbiting distant stars. For those looking for life out there, conventional wisdom says that we should be looking for Earth 2.0; a planet just like ours, orbiting a safe, warm distance from a Sun-like star. Only there will we find the one thing that life needs: water.

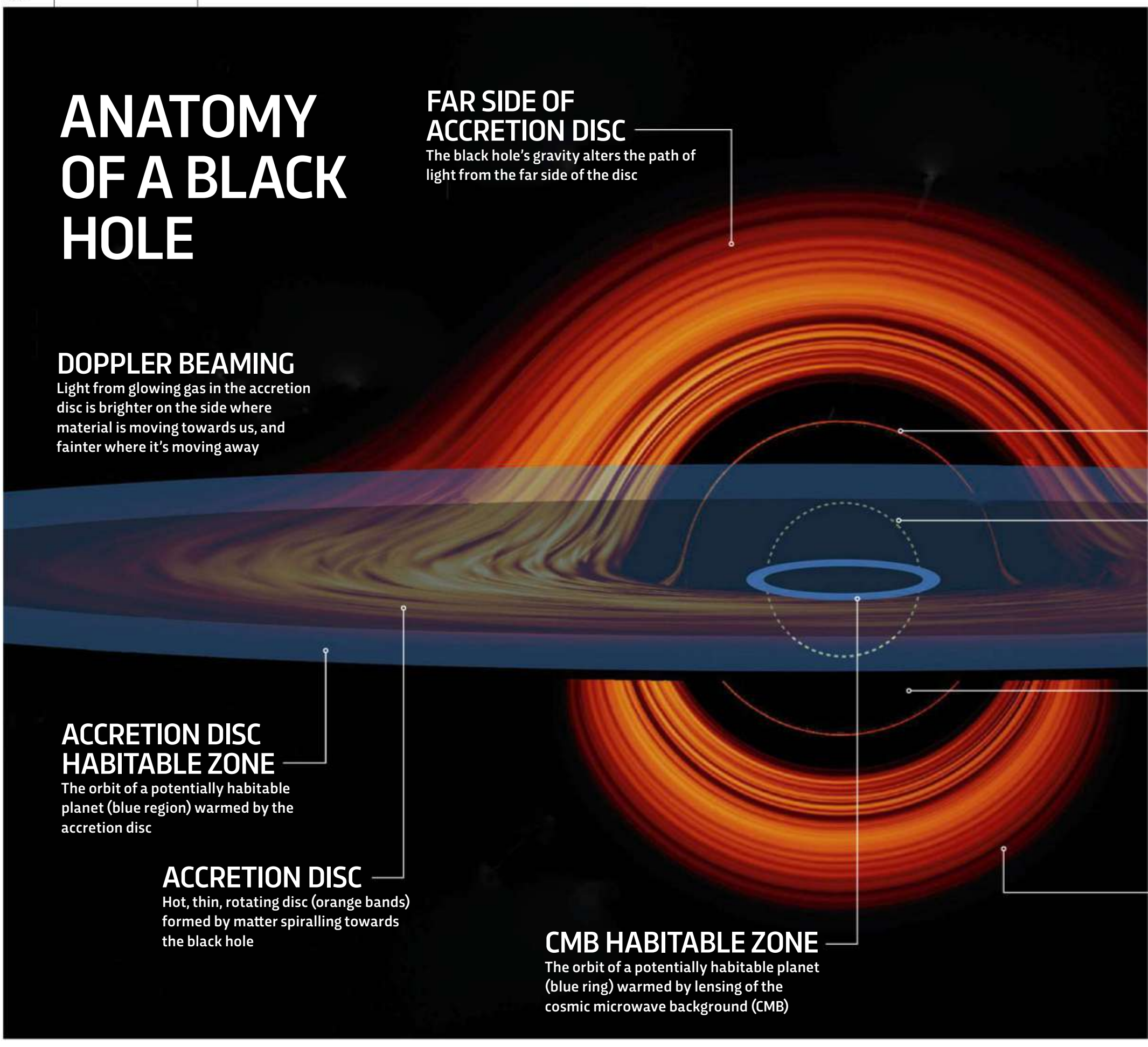
In contrast to life-giving stars, black holes are seen as harbingers of death and destruction. They form when huge stars die and their gravitational pull is so extreme that they act as giant cosmic trap doors. Fall in and you get torn apart with no chance of escape. That hardly seems like the ideal setting for life to develop, but are we missing a trick?

SPACE DUST

Keiichi Wada, from the National Astronomical Observatory of Japan, thinks so. He works on the physics of black holes, but has teamed up with colleagues who research planet formation to see if the idea is plausible. "The two fields [planet formation and black holes] are so different, usually there is no interaction between them," Wada says. They set out to change that by combining their knowledge to model the formation of planets around supermassive black holes, just like Gargantua in *Interstellar*.

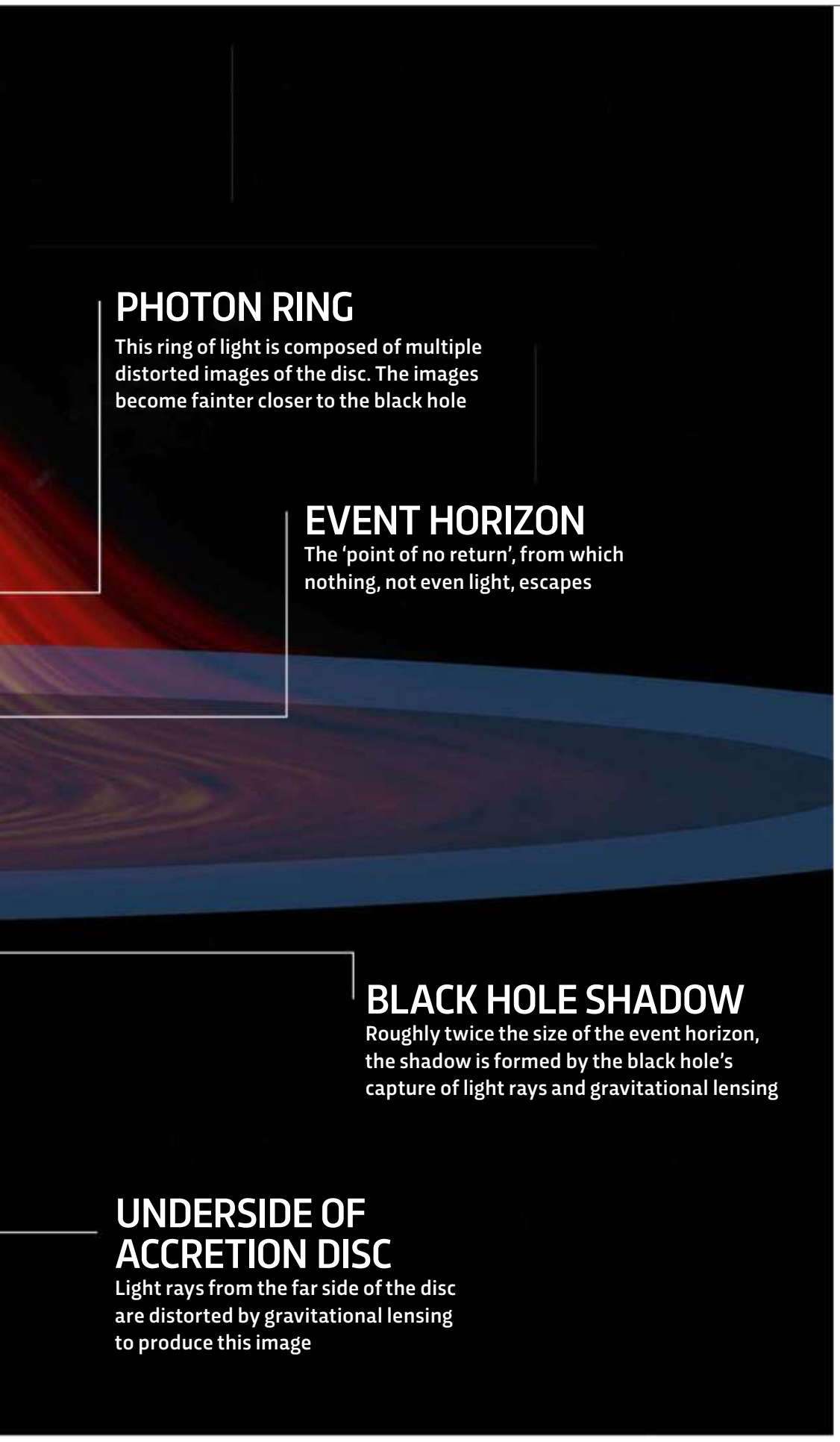
Planets form around stars when gravity starts to collect dust grains together into tiny balls, which then gradually collide with each other to fashion larger and larger objects. Wada and his team wanted to see if this could happen around a black hole. Their model, published last November, shows that at far enough distances from the black hole – at least 10 light-years away – the ➤

"WE EXPECT MORE THAN 10,000 PLANETS AROUND ONE SUPERMASSIVE BLACK HOLE BECAUSE THE TOTAL AMOUNT OF DUST [THERE] IS ENORMOUS. THAT'S A LOT OF UNEXPLORED COSMIC REAL ESTATE"


ANATOMY OF A BLACK HOLE
FAR SIDE OF ACCRETION DISC
The black hole's gravity alters the path of light from the far side of the disc
DOPPLER BEAMING
Light from glowing gas in the accretion disc is brighter on the side where material is moving towards us, and fainter where it's moving away
ACCRETION DISC HABITABLE ZONE
The orbit of a potentially habitable planet (blue region) warmed by the accretion disc
ACCRETION DISC
Hot, thin, rotating disc (orange bands) formed by matter spiralling towards the black hole
CMB HABITABLE ZONE
The orbit of a potentially habitable planet (blue ring) warmed by lensing of the cosmic microwave background (CMB)

gravitational environment is stable enough for planets to form in just the same way as they do around stars like our Sun. "This is the very first study that claims a possibility of direct formation of planet-like objects around supermassive black holes," Wada says. "We expect more than 10,000 planets around one supermassive black hole because the total amount of dust [there] is enormous." That's a lot of unexplored cosmic real estate.

So planets could potentially form around black holes, but that's no guarantee that they offer a life-friendly environment. On Earth, living things are hugely dependent on the light and warmth from the Sun to survive. Without the glow of a star, life around a black hole would likely need an alternative source of energy. Fortunately, that might not be too hard to come by. According to a paper published by NASA's Dr Jeremy Schnittman last autumn, a feature of many black holes – the accretion disc – could stand in for the Sun. The accretion disc is effectively a flat band of material queuing around the black hole waiting to be devoured. As material spirals downwards into oblivion, it ends up travelling incredibly fast and emits huge amounts of energy before it disappears past the point of no return. "All the black holes we know have accretion discs and they are incredibly bright," Schnittman says. According


PHOTON RING
This ring of light is composed of multiple distorted images of the disc. The images become fainter closer to the black hole
EVENT HORIZON
The 'point of no return', from which nothing, not even light, escapes
BLACK HOLE SHADOW
Roughly twice the size of the event horizon, the shadow is formed by the black hole's capture of light rays and gravitational lensing
UNDERSIDE OF ACCRETION DISC
Light rays from the far side of the disc are distorted by gravitational lensing to produce this image

NASA

to his calculations, put a planet at the right distance from the black hole and the accretion disc would appear the same size and brightness as the Sun does in our sky. "It would look very similar to our Solar System," he says.

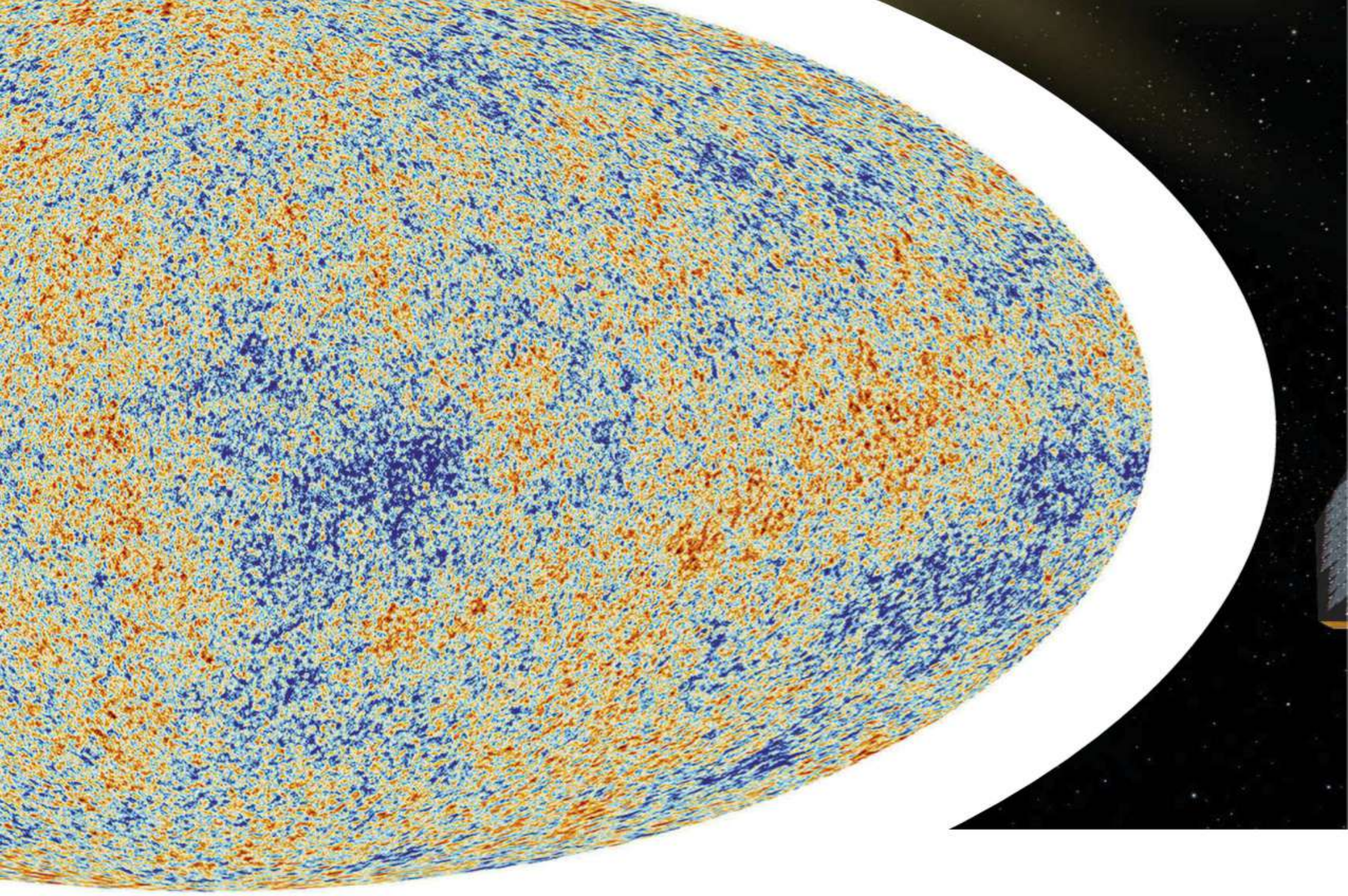
The daytime sky on such a planet may be familiar, but the night sky would be anything but. The centres of galaxies where supermassive black holes usually reside are so jam-packed with stars that, according to Schnittman, the night sky would be 100,000 times brighter than ours. However, those stars aren't neatly spread across the heavens. The gravity of the black hole accelerates the planet to such lofty speeds that the starlight all appears to be coming from a single point in front of you that's smaller than the Sun. "It's like driving into the rain," Schnittman says. Picture a spaceship hitting warp speed in a sci-fi movie. "It would certainly look spectacular."

"PUT A PLANET AT THE RIGHT DISTANCE FROM THE BLACK HOLE AND THE ACCRETION DISC WOULD APPEAR THE SAME SIZE AND BRIGHTNESS AS THE SUN DOES IN OUR SKY"

There is a problem, however, with a planet being warmed by an accretion disc. "They give off a lot more ultraviolet and X-ray radiation than the Sun," Schnittman says. That kind of radiation could potentially sterilise an otherwise habitable planet. "You'd need a cloudy atmosphere to block it," he adds. But that's not impossible given what we already know about the exoplanets we've found orbiting other stars. "Thick, hazy atmospheres seem to be quite common," he says. So you might be able to get away with it being like a constant hot and humid day here on Earth.

FOCUS IN

Given these dangers and restrictions, there may be a safer way to warm worlds around black holes: the leftover energy from the Big Bang. Astronomers call it the 'cosmic microwave background' (CMB), and it was released into the Universe 380,000 years after the creation of the cosmos. According to Dr Pavel Bakala, from Silesian University in the Czech Republic, it could take the place of a star, thanks to an effect called gravitational lensing. Due to their enormous mass, black holes warp the space around them to such an extent that they act a lens. Much like a magnifying glass can set fire to a stick by focusing the Sun's light, so ➤

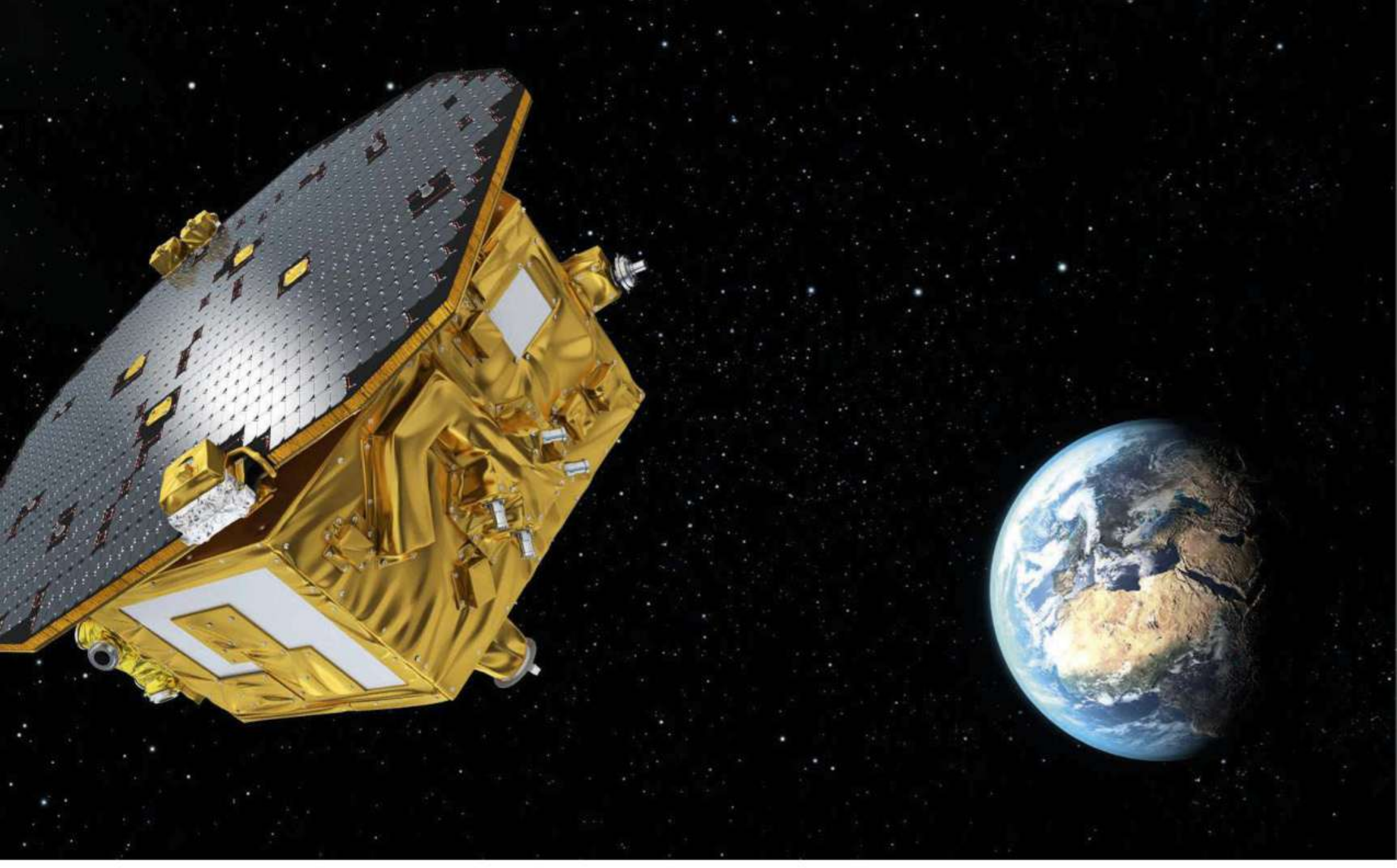


"TIME IS GOING SLOWER THERE BY A FACTOR OF 1,000. SO FOR EVERY 1,000 DAYS THAT PASS ON EARTH – A LITTLE OVER THREE YEARS – JUST A SINGLE DAY ELAPSES ON THE BLACK HOLE PLANET"

the extreme gravity of the black hole can focus the energy of the CMB onto an orbiting planet. Yet Bakala says that on its own not enough, pointing to the fact that on the Earth we cycle through periods of day and night, thanks to the rotation of the Earth. "That helps to circulate the energy around the planet," he says. The respite of night is just as important to a habitable world as the glare of the day. Bakala has a solution for this problem too: the black hole's shadow. As light traverses the extremely warped space around a black hole it creates a ring, with a dark area – the shadow – inside it. This can be seen in the now famous photo of a black hole released by the scientists behind the Event Horizon Telescope in April 2019. A planet passing through this shadow would be plunged into night-time. "That could make it really similar to our experience on Earth," says Bakala.

Not every black hole is suitable, however. "You need a very fast rotating black hole," Bakala says. "It needs to be spinning at close to the speed of light." That's because the slower a black hole spins, the further you have to travel from it to reach a stable orbit. Venture too far and you no longer get the day and night cycle provided by the cosmic microwave background and the black hole's shadow. It's not out of the question, particularly if we look at ancient black holes. The older a black hole, the more chance it has had to spin up as it swallows stuff.

A black hole's age is not the only time-related matter to consider when assessing whether life is likely to be found orbiting one. Black holes mess with time itself. In his General Theory of Relativity, Albert Einstein told us that space and time are interwoven into a fabric called space-time – the famous space-time continuum. So a black hole not only warps the space around it, but time too.



ESA X2

"Time is going slower there by a factor of 1,000," says Bakala. That means for every 1,000 days that pass on Earth – a little over three years – just a single day elapses on the black hole planet. This effect, known as 'time dilation', constitutes a major plot point in *Interstellar*, with one hour passing on Miller's planet for every seven years on Earth. Life on Earth started relatively early – within the first half a billion years or so. For half a billion years to have passed on the black hole planet, the Universe would have to be 500 billion years old. In fact, it formed just under 14 billion years ago. So if life is to be found on a real-world Miller's planet, it would need to spring up considerably faster than it did here.

WOBBLES AND WAVES

According to Dr Lorenzo Iorio, from the Ministry of Education, University and Research in Italy, that life would have to deal with yet another harsh consequence of General Relativity so close to a gravitational monster. A black hole can wreak havoc with a planet's obliquity – how much its rotation axis is tipped over from the vertical. Earth's obliquity is currently just over 23° and it's this tilt that gives us the seasons – summer when we're leaning in towards the Sun, and winter when we're angled away. This tilt varies between 22.1° and 24.5° over a cycle lasting 41,000 years as we get pulled around by the gravity of our neighbouring planets. It's a relatively small change over a long period of time and so we get stable seasons with minimal temperature variations between them. By contrast, the obliquity of a black hole planet is far less stable as it moves through the warped space around its host. "It can vary by several tens of degrees over just 400 years," Iorio says. His calculations, published in February, represent the first time the effects of General Relativity have been taken into account in this way. "It is harmful for the possibility that stable forms of life and civilisations may form and grow," he says.

All this is meaningless unless we can actually find planets orbiting black holes. Thankfully, an upcoming space mission could well be up to the job. In 2034 the European Space Agency (ESA) is planning to launch the Laser Interferometer Space Antenna (LISA) mission. It's an incredibly sensitive detector for picking up gravitational waves – the ripples created as objects move through and distort space-time. "LISA will be sensitive enough to see an Earth-sized black hole planet in the Milky Way," says Schnittman. "For a Jupiter-sized planet you're looking at a thousand times further away than that," he says. That brings another 50 or so local galaxies into the fray, including Andromeda and Triangulum. Maybe then we'll finally know if these sunless, starless worlds of science fiction are really out there. **SF**

by **COLIN STUART** *(@skyponderer)*
Colin is an astronomy author and speaker. Signed books are available at ***colinstuart.net/books***

ABOVE LISA Pathfinder, seen here in this illustration, paved the way for the LISA mission, which is planned for launch in 2034. LISA will pick up gravitational waves, which are the ripples formed in space-time from energetic processes, like black holes

ABOVE LEFT The cosmic microwave background (CMB), as imaged here by the Planck mission, is leftover energy from the Big Bang. Black holes could focus the energy of the CMB, allowing it to act as a star

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COMMENT

TOO GOOD TO BE TRUE?

There are plenty of ethical and environmental reasons to go vegan, but is there a catch?

One of the major health trends of recent years, particularly in more affluent countries, is the move towards a more plant-based diet. Many people are doing it for ethical reasons, but also because we know that large-scale meat production has a significant impact on climate change. So, is there a downside? I recently had a letter from a *BBC Science Focus* reader who wants to put her whole family on a plant-based diet but is anxious about doing so, not least because she has a family history of osteoporosis (thinning bones). So how worried should she be?

If you are a vegetarian then you don't eat meat or fish. But while some vegetarians eat eggs and dairy products (a good source of calcium), others follow a stricter vegan diet and avoid all animal products.

As a vegan, you can still get all the vitamins, minerals and micronutrients you need, including calcium for strong bones, from food, but you might want to consider taking supplements. Remember, though, giving up eating meat entirely won't necessarily make you healthier, particularly if you replace meat with processed food.

This was graphically demonstrated in a piece of research published in the journal *BMC Medicine* in 2013. In the study, researchers followed nearly 450,000 people in 10 countries for more than 12 years. The researchers found, to their surprise, that eating moderate amounts of red meat had no effect on mortality; in fact, it seemed to be protective. The lowest overall mortality rates were in those who were consuming up to 80g a day of meat. The researchers concluded that "a low – but not a zero – consumption of meat might be beneficial for health. This is understandable as meat is an important source of nutrients, such as protein, iron, zinc, several B vitamins as well as vitamin A and essential fatty acids."

"The highest mortality rates were in those eating large amounts of processed meat"

One reason why the vegetarians and vegans in this study weren't, on average, living longer might have been down to a lack of essential micronutrients such as vitamin B12. B12 deficiency can lead to anaemia, fatigue and memory loss; it has also been linked to depression.

Before meat-eaters rejoice, it is worth pointing out that the highest mortality rates were in those eating large amounts of processed meat, like bacon, sausages and salami.

In another study, researchers from Oxford University recorded B12 levels in the blood of 689 men (226 meat-eaters, 231 vegetarians and 232 vegans). They found that 52 per cent of vegans and 7 per cent of vegetarians were vitamin B12 deficient, but only one omnivore.

So if you want to go vegetarian or vegan, it's important to ensure you are getting all your micronutrients. There is lots of useful information on the NHS, Vegetarian Society and Vegan Society websites. **SF**

MICHAEL MOSLEY

Michael is a writer and broadcaster, who presents *Trust Me, I'm A Doctor*. His latest book is *Fast Asleep* (£9.99, Short Books).

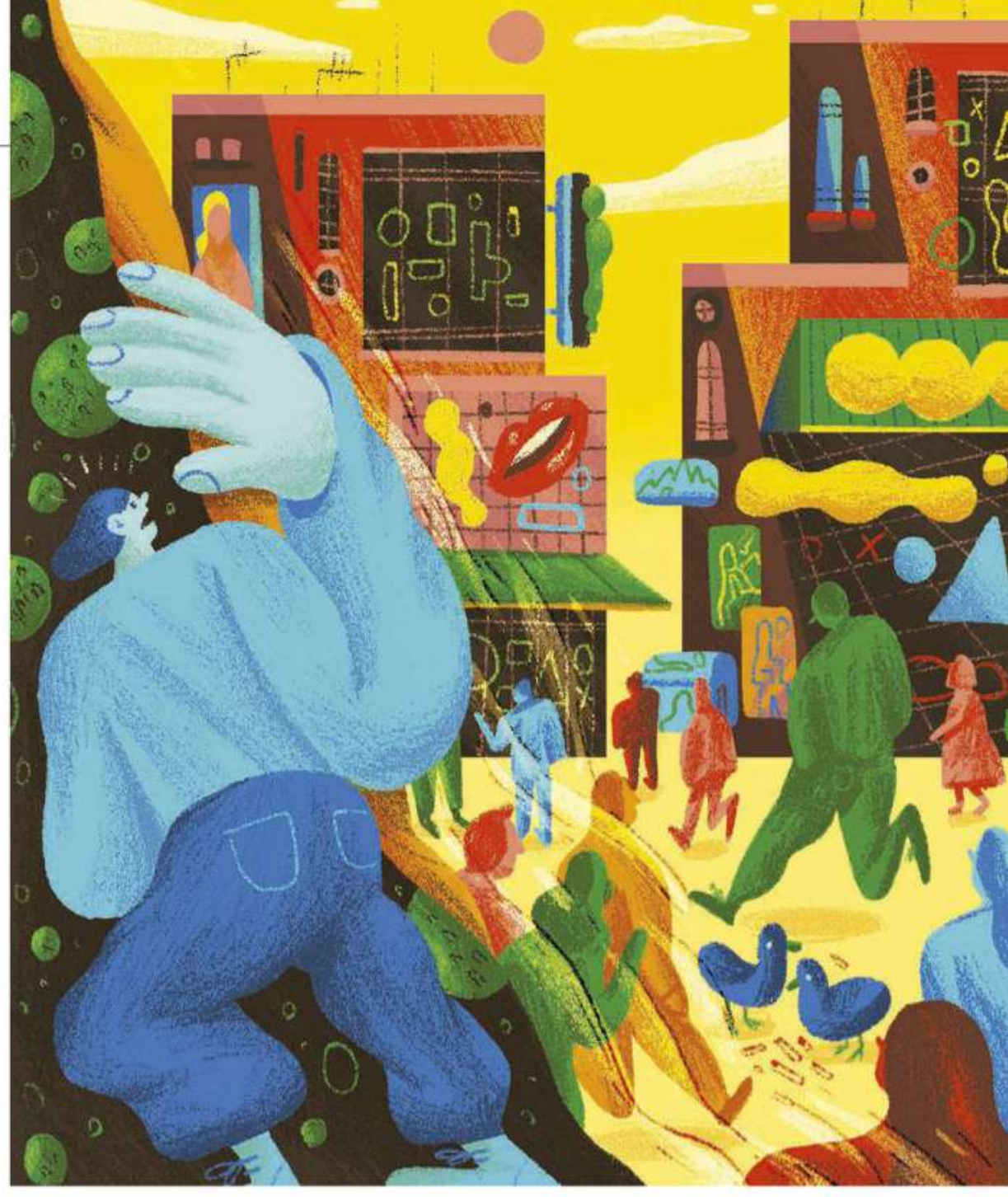
BBC TWO

PORTRAIT: KATE COPELAND ILLUSTRATION: JOE WALDRON

COMMENT

HOW TIMES CHANGE

Shops and restaurants may be slowly opening up, but we have to accept that things may not be as they were for a long time



I can't believe it was only a few months ago that I wrote in this column about how excited I was that theme parks were set to open for the season. A few weeks later, we were confined to our New York City apartment, with home HEPA filters and ambulance sirens our new constant soundtrack. We watched in disbelief as our friends and family in countries with rising numbers of COVID-19 cases blithely tripped out to the pub, to the cinema, to restaurants, to school, to the office. We began to feel like emissaries from a traumatised future, shouting down video calls, "Get inside!" and "Wear a mask!", and "It's coming for you next!". No one believed us. We felt the same impotent rage as the person who sees clearly while everyone else disregards them in every disaster movie ever made.

Now, because of the extraordinary work that this city and its residents have done and continue to do, we are opening up. Being in the epicentre of a pandemic has its privileges: we have widespread testing. Wearing a mask outside is a no-brainer. The subway is cleaner than it has ever, EVER been. With small changes in behaviour, our numbers remain low. On the first day that there were no reported COVID-19-related deaths in the city, we applauded for the frontline workers around the corner at the hospital, across the street at the nursing home, in the funeral home down the block until our hands were bruised.

"Returning to a pre-COVID way of being will put our communities in danger"

Like people in other former hotspots that acted swiftly and decisively, our family is now in the astonishing position of making decisions about how to slowly creep out of our cocoon into a transformed world. And our decisions are full of contradictions: we are avoiding crowded places, but we marched – masked, socially distanced and slathered in hand sanitiser – in a family Black Lives Matter protest. We have a beer with our neighbours, and our kids play together in our connected back garden, but we can't make impromptu autonomous decisions about what we would like to do outside the house, because our actions affect them too. There are so many things we once took for granted that we now interrogate. It can be exhausting.

But look, if the top researchers in the world can't pin this thing down, why should we give in to what we want, rather than what we need? All we want is the 'usual'. In a recent episode of *Digital Human* (**bit.ly/digi_human_normal**), we explain how this desire is obscuring our vision of how the world has changed.

We have no right to return to pre-COVID ways of being; it will put our communities in danger. Tripping back into 'normal' without recognising that things have dramatically changed does a disservice to our human capacity to adapt. No amount of wishful thinking will make our old habits relevant. Until such time as weighing up whether or not it is a good idea to go out, to protest, to travel and to go to a theme park becomes the new normal, we will be reminded of the transformation that has been forced upon us. And then, we will resist change again. SF

ALEKS KROTOSKI

Aleks is a social psychologist, broadcaster and journalist. She presents *The Digital Human*.

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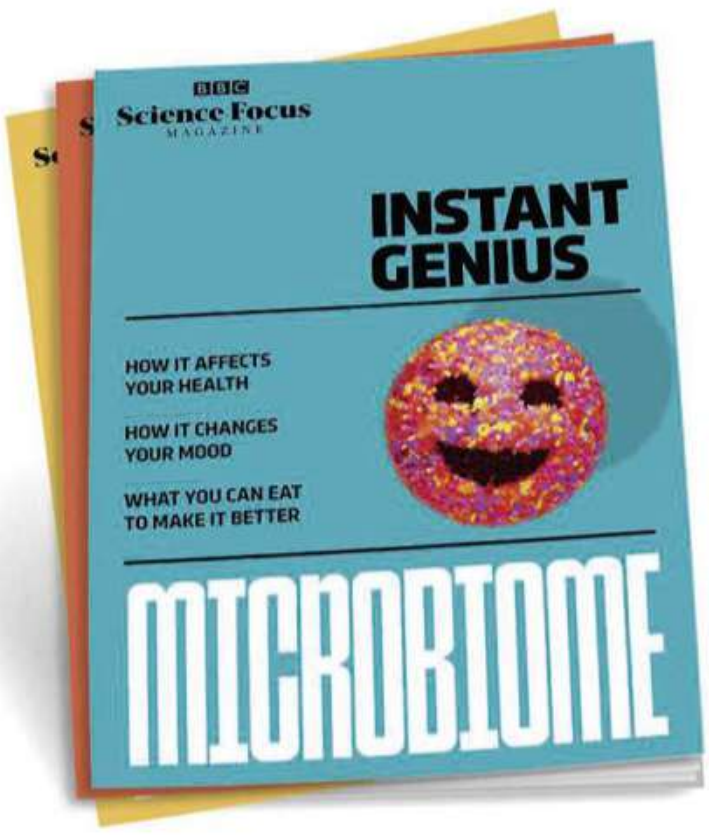
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HOW TO BUILD A BIOBOT

Flexibility, adaptivity and resilience. The future of engineering is biological, says mechanical engineer **Ritu Raman**. **Sara Rigby** finds out how she is integrating biohybrid machines into the human body

IN A FEW WORDS, WHAT DO YOU STUDY?

I'm a mechanical engineer. Typically, you think of mechanical engineers as people who build machines or devices that use materials like metals or ceramics or plastics. I essentially add another set of materials into the toolbox and think about whether we can start building machines using biological materials like living cells.

So, one example of a biological machine that I built is a robot that uses living skeletal muscle to move and walk around. Machines that incorporate biological materials can do pretty interesting things. When you fall and cut your skin, you heal. When you exercise, you get stronger. And it turns out that these robots can do the same thing. When they exercise, they can get stronger and they can also heal from damage.

WHAT DO YOU USE THESE BIOHYBRID MACHINES FOR?

A lot of what we are trying to achieve is just to discover what the design rules and principles of building with biological materials are. For example, building a car is a complex mechanism, but for the most part, most trained mechanical engineers can do all or some part of that. They know that approximately this stiffness of a steel beam is going to take this much force, or a motor they construct in this way is going to produce this much energy and consume this much energy. We have all of these numbers kind of in place, and getting those design rules and principles in place took us thousands of years.

So, a lot of what I'm trying to do in my initial work is to establish what the rules and principles are for building with biological materials. And my focus is to think about whether we can make robots as implantable devices that integrate living biological materials with our bodies. Then they would be able to do things like sense what's going on in an individual system, in response to, say, a disease and adapt to their environment in the way that biological materials do.

WHAT BENEFITS DO BIOLOGICAL MACHINES HAVE OVER A MACHINE MADE OF METAL AND PLASTIC THAT CAN LEARN FROM ITS ENVIRONMENT THROUGH, SAY, ARTIFICIAL INTELLIGENCE?

You know, I think there's a place for innovation using lots of different kinds of materials. There are some places, for example, inside the body in particular, where there's a strong case for using biological materials because they're designed to optimally function in that environment. These materials are soft, they function really well in 37°C human environments, and operate at the same pH of that particular environment.

They also have all of these adaptive capabilities that synthetic materials don't have. Certainly, ➤

DR RITU RAMAN

Dr Ritu Raman is an engineer and writer with a passion for biohybrid design: building machines powered by biological materials that work with the human body to fight disease and damage. She received her B.S. *magna cum laude* from Cornell University and her PhD from the University of Illinois at Urbana-Champaign, and is currently a postdoctoral fellow advised by the renowned Prof Robert Langer at the Massachusetts Institute of Technology. She holds many awards for scientific innovation, including a L'Oréal USA Women in Science Fellowship. She was named in the Forbes 30 Under 30: Science as well as the MIT Technology Review 35 Innovators Under 35.

we've gone some way with synthetic materials. There are some composite materials that, if you scratch them, might be able to seal that scratch. But it's never as strong as it was before. And if you repeatedly scratch the same spot, it gets worse and worse and worse, which doesn't happen to your skin. You might have fallen and hurt your knee when you were five. If you did that again now, maybe it would take a little bit longer, because we're all a little bit older, but it's still going to heal and it's going to return the skin to its original condition, which it wouldn't necessarily do in some of those kinds of materials.

And similarly with AI, we made a tonne of progress in being able to develop machines that can process lots of different signals, compute a pretty complex response and maybe even learn or adapt. But we're still very, very, very far from what the human brain, or brains in general, can do in terms of processing all the different types of signals and making complex decisions or functional behaviours. So I think there's a place [for biohybrid machines].

My interest lies in implantable devices. What can I put inside the body that's safe, that can adapt to its environment, and that I can engineer in some way to have a predictive functional response? I still think there's a strong case to be made that biological materials are your best answer.

WHAT SORT OF BIOLOGICAL MATERIALS DO YOU USE IN THESE MACHINES? IS IT LIVING TISSUE, LIKE YOU'D FIND IN A HUMAN BODY?

Kind of similar. So let's use the example of a walking robot. When we were trying to make skeletal muscle that acts as an actuator that makes this robot walk, we designed something that almost looks like a rubber band.

So we have this sort of mould or a 3D printer and we pattern cells and a mixture of different proteins that mimic their natural environment into this ring-like shape. And what this looks like, at that point, is like if you've ever made any kind of gelatine-based dessert or jello [jelly], it's kind of right before it's about to gel. It's like this gooey mixture. You can pattern it into a bunch of different shapes and then it sets. And that's the same thing that happens with these tissues. They essentially set into this ring-like shape.

Then, because the cells are alive, when they go through this process, they're sensing and responding to their environment. Let's look at the way skeletal muscle works in our bodies. There are individual cells that fuse together to form these long fibres or muscle fibres. That muscle fibre is what's generating force and producing motion. When we stack a bunch of those in parallel, like in our legs or arms, we can generate pretty large forces. So we can do the same thing with these

"Rather than giving everyone the same medicine, why not give them an implant that generates the chemicals their body needs?"

tissues. What happens is the cells proliferate. They reproduce. They get in touch with each other in this ring-like construct, and they fuse to form fibres within that construct.

They essentially remodel their environment and then create the tissue that can generate force and produce motion. And once you get to that point, you can essentially take that muscle ring – which is contractile, or can produce force in response to a stimulus – and you can put it around a skeleton, which is really just like a flexible exoskeleton that can produce different types of motion.

So we focus on something that has two legs and a flexible beam between them, and around those two legs we wrap this muscle. Every time the muscle contracts, it's able to deform that skeleton and the robot inches forward, kind of like an inchworm. It walks or crawls across the surface.

ABOVE This bio-bot has a ring of muscle surrounding a flexible skeleton and has been genetically engineered to respond to light

WHAT ELSE MIGHT YOU USE BIOHYBRID DESIGN FOR? IS IT ALL MEDICAL?

No, I certainly don't think it's all medical. My personal interest is medical, and so I focus on a lot of those applications. As a result, most of the time when I build with cells, I build with cells derived from mammals, because we are mammals and they function in the environment that we've created.

However, there are a few other people working on biohybrid design, and there are folks that focus on a lot of different types of materials. They might use cells derived from insects, for example, which actually function pretty well at room temperature but they also function really well even in air, so they don't necessarily always need to be immersed in a liquid medium.

So if you were thinking of maybe having an untethered robot that could, say, move in our ambient environment either to work in a factory or perhaps go in a water stream to sense a source of pollution and neutralise whatever toxin it was in that environment, that's the sort of thing where you might want to think about using cells from an insect or maybe cells from bacteria. And those are all certainly very valid and useful applications.

WHERE DO YOU HOPE THIS RESEARCH WILL LEAD?

My focus always returns to medical implants because I think one of the biggest trends that we see in medicine today is this idea of precision medicine or personalised medicine. From experience, we know that different cancer patients can go into a clinic and get essentially the same therapy, with some people responding really well to the treatment and yet other people don't.

Rather than giving everyone the same medicine, why not give them an implant that can generate the chemicals that their body needs, or sense that this person needs a little bit more at this time, or that person doesn't. If we place certain cells that secrete insulin in a diabetic, for example, these cells could potentially automatically regulate how much insulin they're secreting for the needs of that individual person at that time.

I think the most interesting thing that I'm doing right now, is working towards using the skeletal muscle that I've developed in the lab as a potential implant to replace skeletal muscle that's been lost due to disease or damage. This is something that I just think is a really meaningful cause. It matters a lot to me. I think mobility is something that a lot of us take for granted. And when you lose it, it can have a significant impact on the quality of your life.

A lot of a lot of people have tried to do this over the years, and we've understood a lot by building these robots. How do you tune it to respond to its environment and how you generate really, really large forces from compact volumes? I would love to be able to contribute any small part to helping restore the mobility to somebody who's lost it. SF

Remotely operated underwater vehicles help us explore the oceans at depths that would be impossible for divers

AN OCEAN OF MYSTERIES

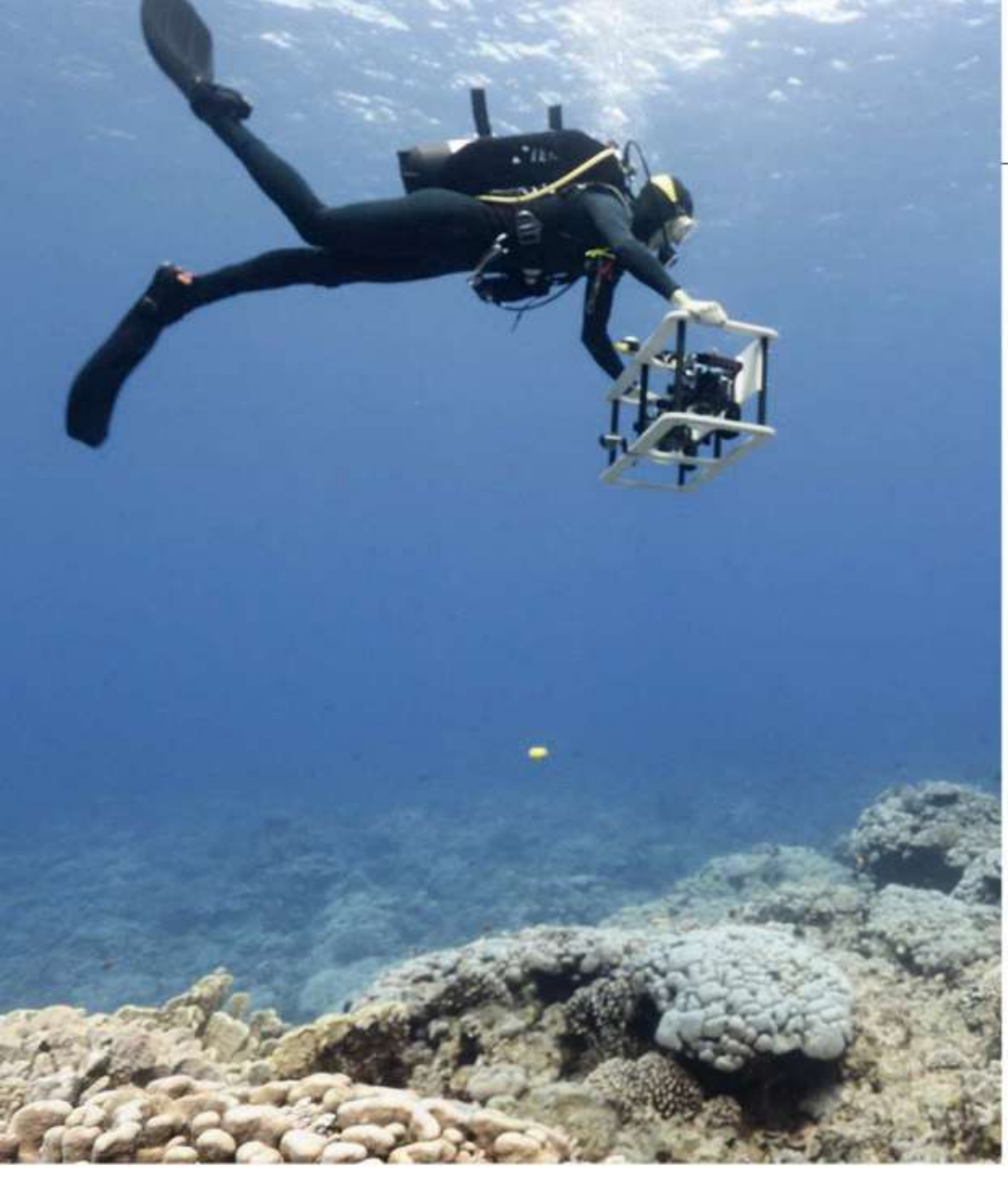
Earth's biggest habitat is also the one that we know the least about. Now, a new wave (geddit) of innovators are engineering the technology that will help us find out more. Here's what they are discovering...

WORDS: DR HELEN SCALES

The oceans are the biggest, wildest, least understood part of the planet. But we're getting to know them better every day, thanks to a host of technologies that are fathoming the depths in new and inventive ways. Some researchers are capturing things from the sea and transporting them into the lab to study in detail; others are rigging the oceans with novel sensors and devices, or probing them with algorithms. Together, these approaches are offering brand new views of the underwater world, at a time when it's never been more important to decipher the inner workings of the oceans.

From coral reefs to deep-dwelling jellies, the oceans' living inhabitants face greater threats from human activities than ever before. The seas are polluted and overfished, marine habitats are being destroyed, and new impacts – such as deep-sea mining – are fast approaching. It's also becoming increasingly clear just how critical the oceans are for the rest of life on Earth. These enormous, ever-shifting waters play a vital role in weather and climate systems, provide food and livelihoods for human populations around the world, and are home to great swathes of unknown biodiversity. In order to understand and protect life on this planet, we have to look to the oceans.

GETTY IMAGES



VIRTUAL E-REEF BUILDERS

Not so long ago, the main way that marine biologists studied coral reefs was to scuba dive for an hour or so at a time and note down what they saw on waterproof slates. Now, during a single dive, they can take photographs that can be stitched together into an intricate, three-dimensional view of the reef. "It's underwater virtual reality," says Prof Stuart Sandin, a marine biologist at Scripps Institution of Oceanography, UC San Diego. "It makes you feel like you're immersed."

Using a system with two cameras rigged at different angles, a diver swims up and down a reef as if they are 'mowing the lawn'. Around 3,000 images taken from standard 10 x 10m plot are then analysed by computer using a technique known as 'structure from motion'. The result for a 10 x 10m plot is a three-dimensional digital model of the reef, made up of a billion coloured dots.

The technique, which took Sandin years to develop by collaborating with teams of computer scientists and engineers, is now being rolled out around the world. So far 30 hectares of reef have been mapped, equivalent to dozens of city blocks, at a resolution of one millimetre. Besides producing stunning underwater vistas, all sorts of valuable information can be extracted from these e-reefs.

At Boston University, undergraduate student researcher Coretta Granberry meticulously traces on a digital tablet the outlines of individual corals, so she can calculate their areas and make comparisons over time. "You get a very detailed, intimate image of the reef and how everything is connected," she says.

The corals she studies are growing thousands of miles away, in the Phoenix Islands in the middle of the Pacific. Her professor, Dr Randi Rotjan, leads expeditions every three to five years to these extremely remote reefs. "Out there, the closest people to you are on the International Space Station," says Rotjan. These isolated, protected islands are helping to show how reefs respond to rising sea temperatures. "If you leave reefs alone locally, what are they going to look like when global change is the only stressor?" says Rotjan.

Armed with images taken from the same plots in 2012 and 2015, Granberry and her colleagues will track how the individual corals in the Phoenix Islands change, to see if they shrink, grow or get overgrown by something else. As time capsules, e-reefs will allow scientists in the future to wind back the clock and answer new questions that nobody can anticipate. "You're in essence exploring in four dimensions," says Sandin.

E-reefs are also a powerful tool for showing what the reefs are like right now. "You watch everyone's eyes glow, from the most seasoned scientists, to a politician, to a community leader, to a child," says Sandin. This is especially important in the Phoenix Islands Protected Area, where local people of Kiribati who drove the conservation efforts live too far away to visit the reefs across the enormous archipelago. "E-reefs become the mechanism to show people in country what they're protecting, and why," Rotjan says.

SCRIPPS INSTITUTION OF OCEANOGRAPHY AT UC SAN DIEGO X2, PENNY HOLLIDAY/NOC

CLIMATE PREDICTORS

Between Scotland, Greenland and the eastern coast of Canada, an array of underwater sensors stretches for more than 3,000 kilometres. Prof Penny Holliday from the UK's National Oceanography Centre describes the array as a picket fence. She's the UK principal investigator of OSNAP, the Overturning of the Subpolar North Atlantic Programme, which installed the 58 sensors in 2014. Each sensor consists of a giant, air-filled ball that sits near the ocean surface. The ball is fixed to the seafloor thousands of metres below via a mooring line. The ball's buoyancy keeps the mooring line upright, and along the line's length are various instruments that measure water temperature and salinity, as well as the speed and direction of currents flowing past. The aim is to monitor the subpolar gyre, which is a massive current of warm water that swirls anticlockwise across the North Atlantic. The gyre releases heat to the atmosphere, which flows over the UK and Europe. "That's what keeps us warm," says Holliday. We can see this effect by comparing temperatures of the UK or Europe with the same latitude in Canada. The difference is caused by the heat brought to us by that large-scale ocean circulation.

The Atlantic's subpolar gyre is part of a global process called 'overturning circulation'. This is the process by which warm, shallow seawater flows from the tropics towards the poles, where it gradually cools, becomes denser and sinks, then flows back towards the tropics again. It plays a key part in climate models, distributing heat and carbon around the planet, but in the North Atlantic it's not well understood. Until the array was installed, scientists had no idea how strong the overturning circulation was at this latitude, or how it changed over time.

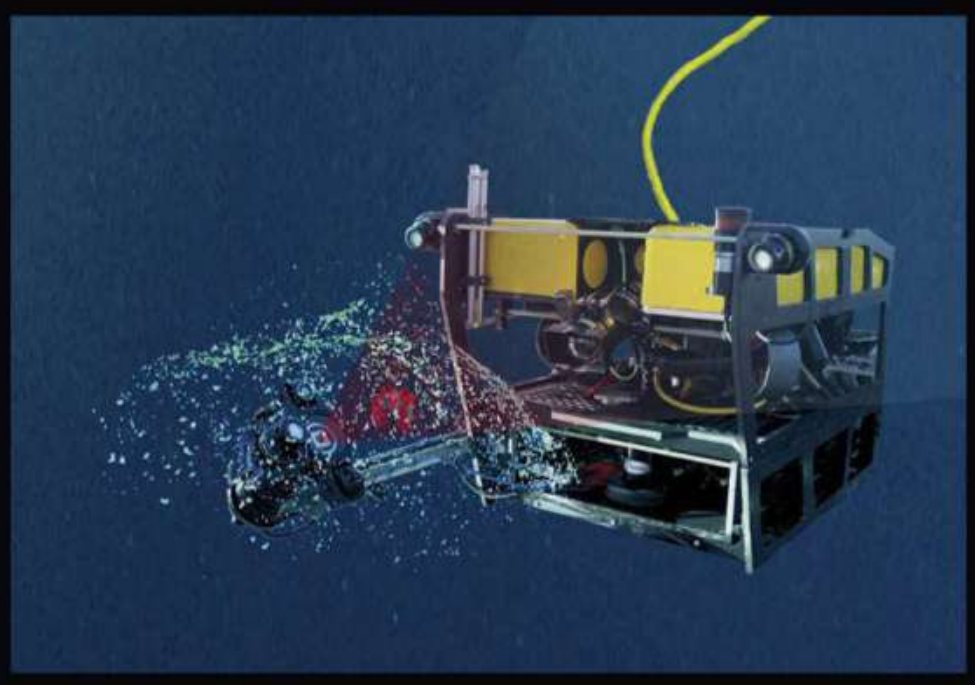
From the first few years of data, Holliday and her team have begun to get a handle on it. "Even just getting those [first] numbers feels like a huge step forwards," she says. "The interesting thing we found is just how variable it is." They also realised they'd been wrong in assuming that the most important place for the overturning circulation was between Canada and Greenland in the Labrador Sea. In fact, the centre of action lies between Greenland and Scotland. "That doesn't sound very exciting, but it's important for the way we interpret climate models and the predictions we make about changing climate," she says.

The OSNAP array will stay in place until at least 2024, to continue monitoring the gyre and boost the confidence of future climate predictions. Holliday's team are also bolting on new devices to measure oxygen levels. "One of the big questions in the world at the moment is an issue of whether the ocean and some shelf seas are losing oxygen," she says. "We're able to build on this array that was designed for another purpose to get extra information, which is really exciting."

ABOVE LEFT A researcher swims up and down the coral reef with a camera, taking thousands of pictures. These will be stitched together to create a 3D photomosaic to help analyse the reef

ABOVE A photomosaic of a coral reef in the Palmyra Atoll, which was created from 2,700 individual images

RIGHT These ball-like devices float just below the ocean surface and are connected to the seabed by mooring line. The line has sensors located along it to measure different water variables



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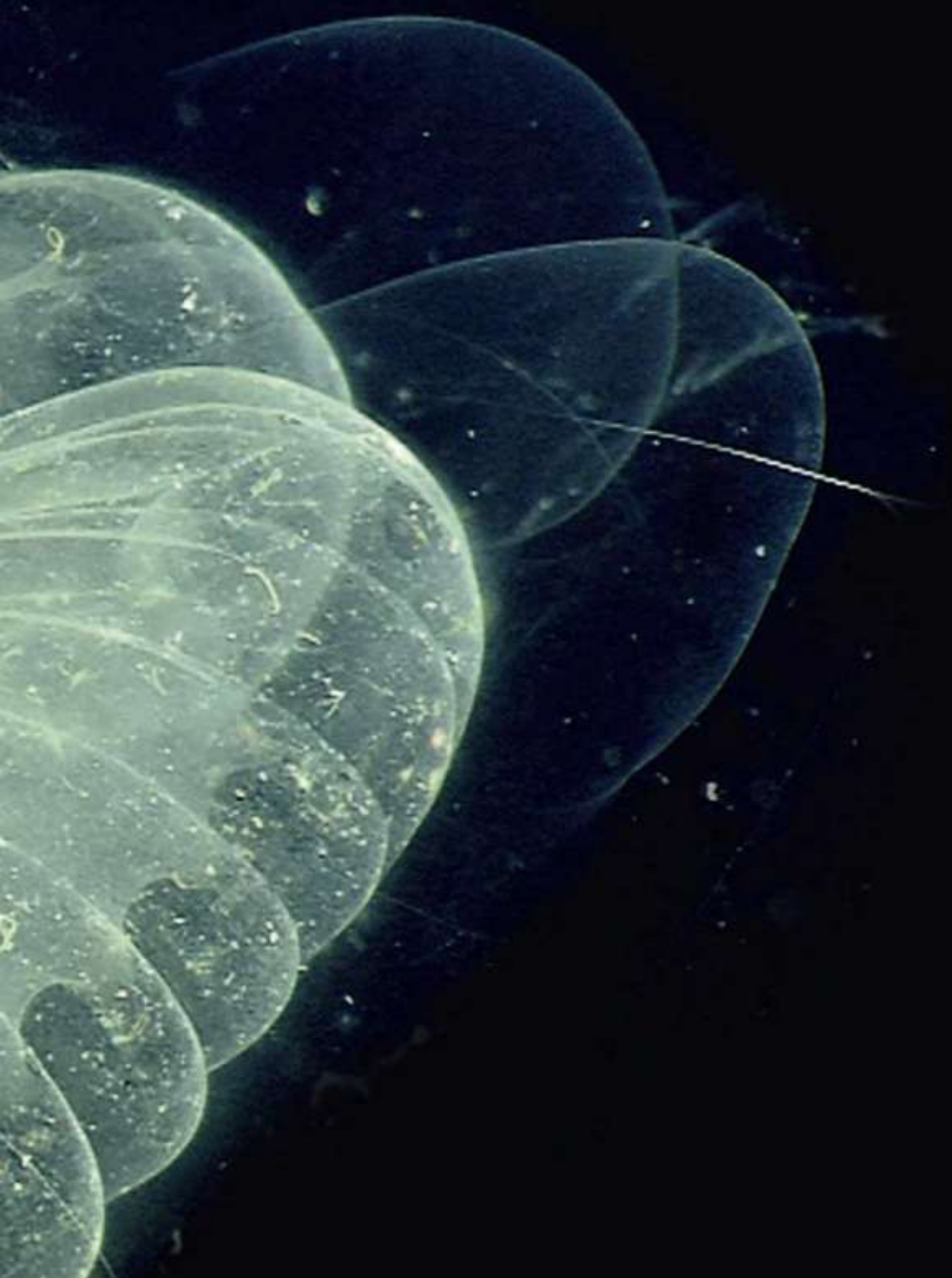


DEEP-SEA CURATORS

Floating through the deep sea are multitudes of intricate, gelatinous animals that are extremely difficult to study. They're transparent, and so delicate that they easily fall apart when caught in nets. But now a team from the Monterey Bay Aquarium Research Institute (MBARI) in California has developed a new way of looking at them.

Dr Kakani Katija, MBARI's principal engineer, has designed the DeepPIV (Particle Imaging Velocimetry). Attached to a deep-diving robot, the device uses a sheet of lasers to build 3D scans of transparent, intricate animals in their natural environment. Katija's first targets were 10cm-long, tadpole-like animals called giant larvaceans, which make complex mucous structures to filter seawater for tiny food particles. The animal's fist-sized filter looks a bit like a pair of fluted angel wings. "From an engineering perspective, these are some of the most amazing built structures I've ever come across," says Katija.

Her team at MBARI's Bioinspiration Lab used DeepPIV to scan the inner shape of a larvacean filter, and also tracked particles as the animal beat its tail and drew in water. This information will help them figure out how the filters work and how the animals build them. Already, DeepPIV has revealed that larvaceans filter 80 litres of water per hour and absorb masses of carbon-rich food. When they get clogged, the larvaceans jettison their filters, which then sink, therefore helping the oceans to take carbon into the deep. In fact, larvaceans are so abundant throughout the oceans that they play an important role in the carbon cycle.

Other researchers are interested in using DeepPIV, including people who are rethinking ways of exploring the ocean. "These 3D visualisation techniques, coupled to DNA extraction, may be sufficient to describe and catalogue life," Katija says. In the future, rather than collecting and preserving dead animal specimens — which is especially tricky for delicate, gelatinous life forms — museums could use 3D scans as digital archives to help describe previously unknown species and document life in the vast deep oceans.

ABOVE Close-up view of the filter on a larvacean. The DeepPIV has helped researchers find out how the filters work, without damaging the animals

FAR LEFT Illustration of a remotely operated underwater vehicle (ROV) with the DeepPIV system attached

LEFT Dr Kakani Katija works in the control room, as an ROV uses the DeepPIV system to illuminate a larvacean

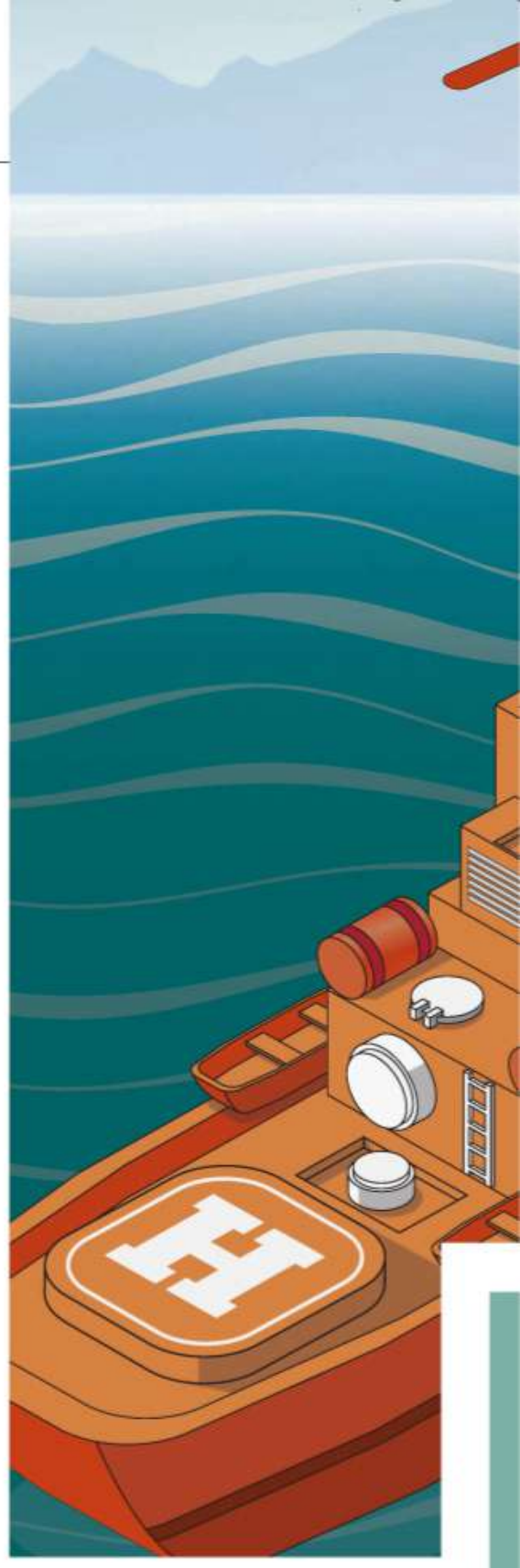
CASTAWAY HUNTERS

When someone goes missing at sea, search and rescue plans are usually drawn up using data on weather, currents and water conditions to predict their likely trajectory. The problem is that errors can quickly accumulate until the predicted pathway is a long way adrift from what's actually happening at sea. A new algorithm could improve the chances of locating people by predicting not their trajectory, but where they will end up. The algorithm analyses strength and direction of ocean currents, waves and surface winds, and identifies in real-time the regions of the ocean called TRAPs (TRansient Attracting Profiles), where floating objects are likely to converge.

Dr Mattia Serra, now a Schmidt Science Fellow at Harvard, developed the algorithm during his PhD with Prof George Haller at ETH Zurich. He likens TRAPs to a table on which magnets continually pop up, disappear and move. "Then throw a coin on the table," he says. "The trajectory of the coin is very chaotic because it's going to feel the influence of all these magnets." The table is the ocean surface, the magnets are TRAPs, and the coin is a drifting person.

During tests, the algorithm was found to work well out in the turbulent sea off the Massachusetts coast. The team, led by MIT's Prof Thomas Peacock, used a snapshot of local conditions to model the ocean's behaviour and locate where the TRAPs were likely forming. Then they simulated a search and rescue mission, casting buoys and manikins into the sea, each carrying a GPS tracker. As predicted, the objects drifted towards the identified TRAPs.

Serra and his colleagues are now discussing the possibility of the US coastguard using the algorithm in search and rescue operations. The algorithm could also be used to more accurately predict the movements of oil spills.



ABOVE A computer algorithm can analyse rapidly changing ocean conditions and accurately identify the TRansient Attracting Profiles (TRAPs) where people lost at sea will converge

LEFT In tests, manikins were thrown overboard with GPS devices attached. As predicted, the objects drifted towards identified TRAPs

RIGHT It's vital to find out where in the ocean microplastics exist. A device designed by a team of scientists from the UK and Japan uses lasers to monitor water samples and identify plastic particles

BELOW The ProSPA chemical analysis lab is being developed by the Open University and will

PARTICLE DETECTORS

To tackle the growing problem of plastic pollution in the oceans, it's vital to know where plastics are, where they move and what they're made of – especially flurries of microplastics. These tiny plastic particles are smaller than 5mm in size, and can be difficult to find.

"At the moment, if you want to know the distribution of particles in the deep sea you have to sample them," says Dr Tomoko Takahashi, postdoctoral researcher at Japan Agency for Marine-Earth Science and Technology (JAMSTEC). That takes time, either using nets or water bottles, which have to be hauled up to a ship and sent off for laboratory analysis. Researchers from the University of Southampton, the University of Aberdeen, JAMSTEC and the University of Tokyo, are developing a prototype particle detector that could soon automate the process and help monitor plastics, as well as other tiny particles – natural or human-made – in the deep sea.

Their device consists of a 20cm chamber, which seawater flows along. The chamber contains a single laser, and when a particle is present it scatters the laser light, creating a high-resolution holographic image. This can help to identify the particle, be it plastic or plankton. The same laser also analyses the chemical make-up of the particle, using a method called Raman spectroscopy. In tests, the device has successfully distinguished between 3mm pellets of polystyrene and acrylic.

The team's ultimate goal is to produce a fully automated device that could continuously monitor the oceans. Fixed to floats or gliders that cruise around the ocean gathering data, the particle detectors could be deployed for months, even years at a time, beaming back information on the types and abundance of plastics and other particles all through the oceans. SF

by **DR HELEN SCALES** *(@helenscales)*

Helen is a marine biologist, broadcaster and author. Her next book, The Sea Beneath Us *(£16.99, Bloomsbury Sigma), will be out in February 2021.*

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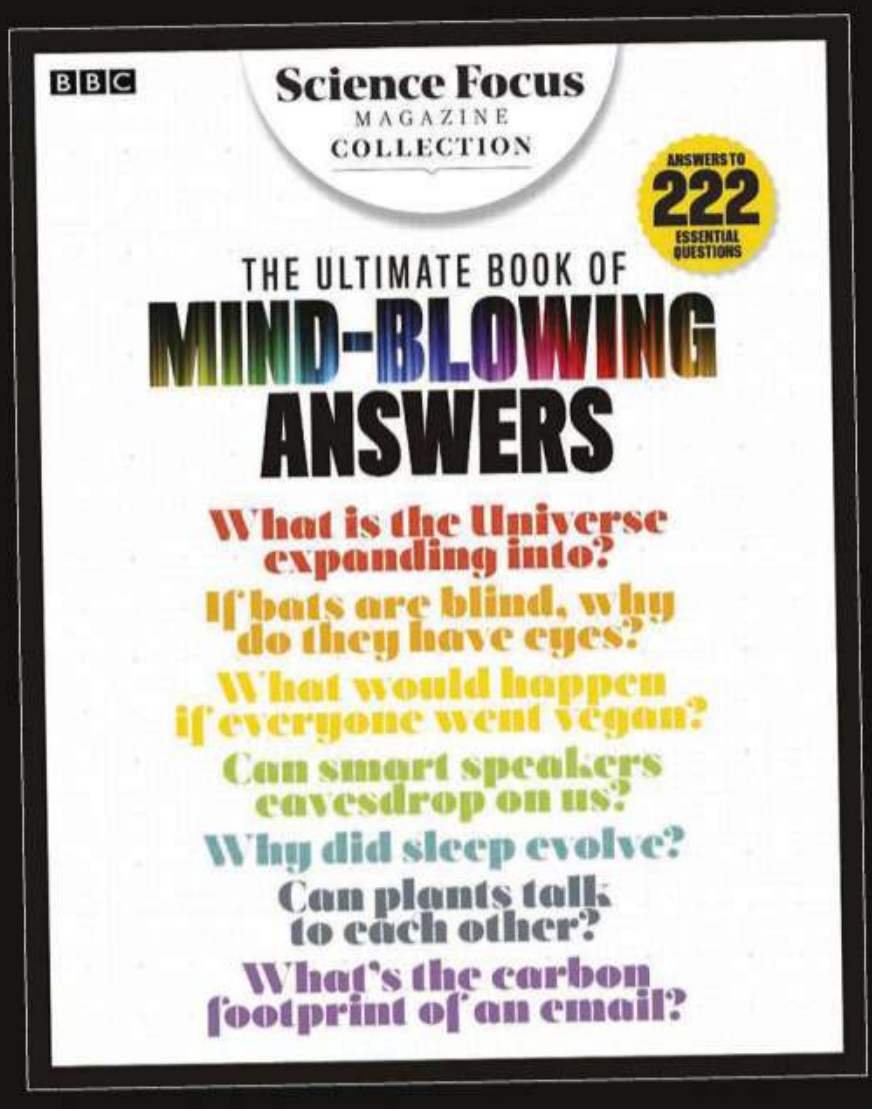
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... WHY DO SPOTS TEND TO APPEAR ON THE NOSE AND FOREHEAD?
... WERE THE EGYPTIAN PYRAMIDS BUILT BY SLAVES?
... HOW CAN I SPOT THE ISS?
... WHY DO EGGS TASTE SO DIFFERENT, DEPENDING ON HOW THEY'RE COOKED?
... HOW DOES EVOLUTION WORK?

Email your questions to
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or submit on Twitter at
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OUR EXPERTS

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Astronomer, astrophysicist

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Palaeontologist, dinosaur expert

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Science writer and editor

LUIS VILLAZON
Science and technology writer

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DR HELEN SCALES
Marine biologist, science writer

DR BRENNA HASSETT
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PROF ROBERT MATTHEWS
Physicist, science writer

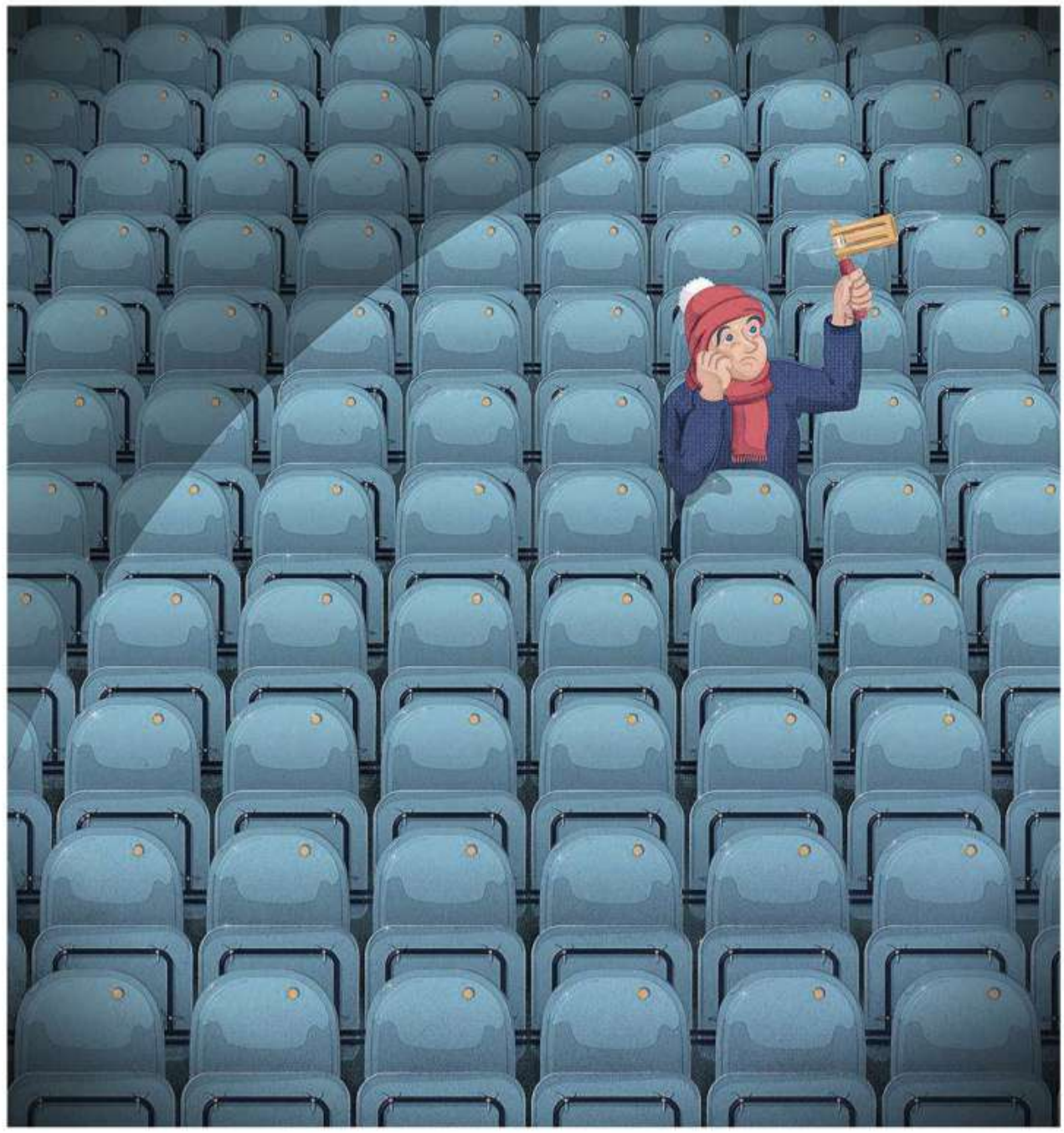


ILLUSTRATION: DANIEL BRIGHT

BRADLEY COOK, LONDON

WHY IS WATCHING FOOTBALL ON TELEVISION WITHOUT CROWD NOISE SO STRANGE?

Watching post-lockdown football matches without crowd noise can be a surreal experience. That's partly down to the sheer novelty of the situation: we rarely see football played in empty stadiums. Take away the cheers, chants, boos and heckles, and it's as if a key part of the emotional experience is missing, like biting into a crisp and getting no crunch. It also takes away the communal aspect of watching the game. Without that soundtrack of impassioned fans, watching it at home can feel more solitary.

Thinking about it from a psychological perspective, a key part of our conscious experience is based on the way our brains are constantly anticipating what sensations are likely to come next and when. A goal without a celebratory roar is not what the brain expects, so it disconcerts us. An artificial crowd noise track that's out of sync with the action on the pitch (as has been reported by some fans) is potentially even worse: it creates a jarring mismatch between what we expect and what we actually see and hear.

For players, an empty stadium brings its own challenges. The supportive noise of a loyal crowd is a key component of the well-established home advantage. Early results after lockdown in both the Premier League and Germany's Bundesliga suggested that home advantage was weaker than pre-lockdown. Also, with no crowd to entertain (and less crowd encouragement for the players to feed off) we might expect players to perform with more caution and less flair, leading to cagier matches. ***CJ***

DEAR DOCTOR...

DELICATE ISSUES DEALT WITH BY *SCIENCE FOCUS* EXPERTS

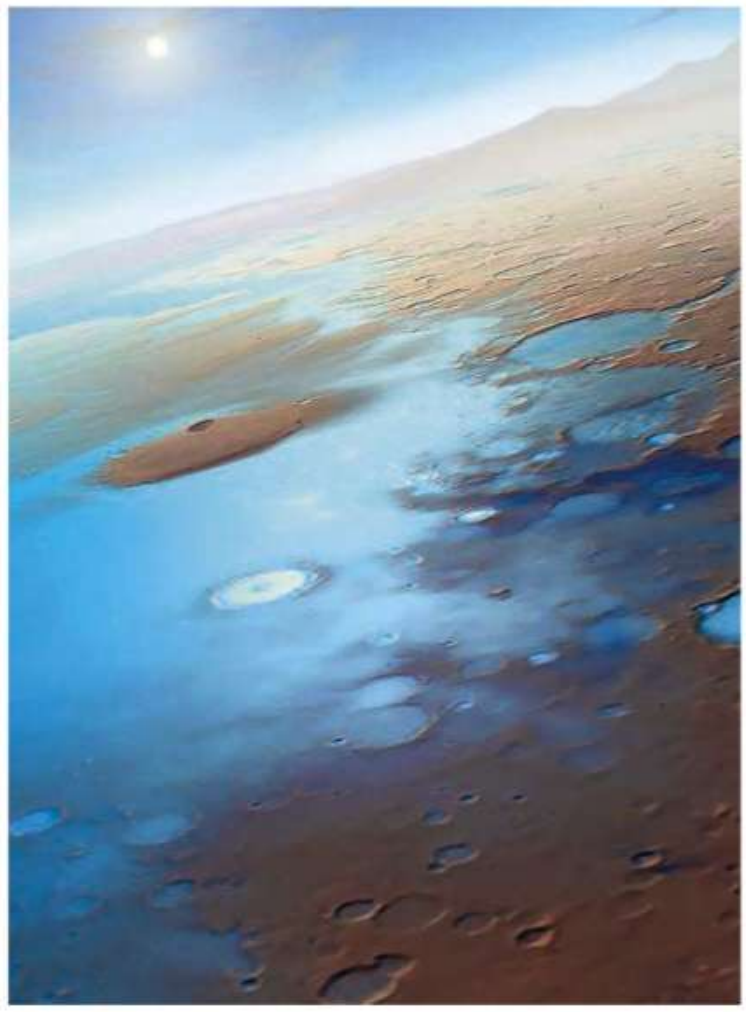
THE LOCKDOWN HAS MEANT MY STEP COUNT HAS DROPPED FROM 10,000 TO 7,000. SHOULD I BE WORRIED?

There's no denying that walking is good for your health, but there's nothing magic about the number 10,000. This figure is thought to have come from a Japanese pedometer called 'manpo-kei' (literally '10,000 steps meter'), marketed as a device for the health-conscious in the run-up to the 1964 Tokyo Olympics.

The 10,000 steps target has probably stuck around because it's easy to measure and easy to remember. But a 2019 study led by researchers at the Harvard Medical School measured the step counts of almost 17,000 women over four years and found that the benefits tapered off well before 10,000 steps. The least active women averaged about 2,700 steps per day, and increasing this to 4,400 steps was associated with a 40 per cent drop in mortality rates. Higher daily step counts showed greater benefits, but only up to 7,500 steps per day, at which point mortality rates levelled off. This study only looked at older women (average age of 72), and there will have been many factors other than step count that affected their likelihood of dying within the four years. But the wider conclusion is that fixating on the number of steps isn't necessarily helpful. A better – and perhaps more attainable – goal is 150 minutes of moderate exercise per week, including brisk walking. ***LV***

ASEER AWSAF

HOW DID MARS LOSE ITS ATMOSPHERE?



Mars today has a thin atmosphere: the volume of gases (mostly carbon dioxide) in its atmosphere is less than 1 per cent that of Earth's. However, evidence from the surface of Mars indicates that the planet was once much warmer and wetter than today. This suggests that the Martian atmosphere must once have been much thicker, creating a strong greenhouse effect that trapped the Sun's light.

Thanks to numerous missions to the Red Planet, we now know that in its early infancy, up until around four billion years ago, Mars had a strong magnetic field, created, just like Earth's, by convection currents of molten metals in the planet's core. But, unlike Earth, Mars cooled enough internally to switch off this mechanism, and the planet ended up with no global magnetic field. Without this magnetic field, the planet was less protected from the solar wind – the stream of energetic charged particles flowing from the Sun.

The solar wind stripped away most of the Martian atmosphere in only a few hundred million years after the planet lost its magnetic field. This process was quick because the Sun rotated much faster in its youth, which made the solar wind more energetic. The loss of a large fraction of its atmosphere to space was a major cause of Mars's transition from a warm, wet climate to today's cold, dry one. In contrast, the fact that the Earth retained its magnetic field, which deflects the solar wind, and hence held on to its atmosphere, ultimately allowed life to develop here. ***AGu***

SIMON BARTLETT

HOW DO SHUFFLE FEATURES ON PLAYLISTS ACTUALLY MAKE THEIR SELECTIONS?

Shuffle is supposed to play our music in a random order. But a truly random algorithm would pick any song from any album, and this might result in two or three songs in a row from the same artist, particularly if we have a lot of content from that artist. This doesn't feel random to the user, so most shuffle algorithms try to ensure that consecutive songs are from different artists and albums. Some algorithms go further and only choose songs from the last 100 you listened to, with the intention of presenting more of the songs you prefer. In fact, this 'random' list may be exactly repeated if you keep listening! ***PB***

CROWDSCIENCE

Every week on BBC World Service, *CrowdScience* answers listeners' questions on life, Earth and the Universe. Tune in every Friday evening on BBC World Service, or catch up online at **bbcworldservice.com/crowdscience**

HOW DOES HUMAN NOISE AFFECT OCEAN LIFE?

The background volume in the oceans has roughly doubled in intensity each decade since the 1950s, due to more shipping. Meanwhile, military sonar devices blast out acoustic waves, as do the underwater airguns used in seismic surveys for oil and gas deposits.

In noisy seas, whales and dolphins have trouble communicating with each other; some sing or whistle louder, while others give up and fall silent. Sonar seems to disorientate these animals, making them more likely to ascend too quickly and suffer decompression sickness.

In lab studies, scallop larvae exposed to noise pollution develop deformed bodies, fish are deafened, and jellyfish, squid and octopuses suffer damage to their balance organs ('statocysts'), which impairs their sense of orientation. Airguns can also kill tiny zooplankton from more than a kilometre away.

As with plastic pollution, it's not yet clear how noise pollution impacts entire populations or ecosystems. To find out more, scientists make the most of opportunities when shipping stops and the oceans quieten – such as during the coronavirus pandemic, when hydrophones registered reduced noise levels as far as 3,000m underwater. We don't yet know how marine life has responded to this hush, but a long-term study of right whales in Canada's Bay of Fundy offers a hint. The study found lower levels of stress hormones in the whales' faeces when shipping was halted following the 9/11 attacks. As the noise ramped back up, the whales got stressed again. ***HS***

GETTY IMAGES X3 ILLUSTRATIONS: DANIEL BRIGHT

DHYEY, INDIA

IS IT SAFE TO FLY A KITE IN A THUNDERSTORM?

No, it isn't – though it does have its place in the history of science. In June 1752, the American polymath Benjamin Franklin flew a kite during a storm, using it to investigate his theory that lightning is a form of electricity. Knowing the wet string could conduct electricity, he thought he could protect himself by standing in a doorway and looking for signs of electric charge on the dry part of the string, rather than waiting for a direct strike. But he was still very lucky. He doesn't seem to have realised that as voltages during storms allow electric currents to flow even through air, the dry string would not have stopped a lightning strike reaching him – with potentially fatal consequences. ***RM***

31

The percentage of lemur species classified as critically endangered – that's 33 out of 107 species.

AMY-GRACE ENZER

WHY DO SPOTS TEND TO APPEAR ON THE FOREHEAD AND NOSE?

Spots are caused by bacterial infections in the pores of your skin. Each pore has a 'sebaceous gland' that produces a mix of oils called sebum to lubricate the skin and the hair that grows out of the pore. The skin on your nose and

forehead produces more sebum than other areas of the body, and without long hairs growing from those pores to take away some of the sebum, it's easier for the sebum to clog the pore, allowing trapped bacteria to multiply out of control. ***LV***

NATURE'S WEIRDEST CREATURES...

THE RED-LIPPED BATFISH

The red-lipped batfish flaunts its outrageous scarlet pout with all the charisma of a 1980s goth frontman. No one knows exactly why the batfish sports its signature look, but it may help it to attract mates, or to recognise others of the same species at spawning (reproduction) sites.

The red-lipped batfish lives at depths of up to 75 metres in the waters surrounding the Galápagos Islands, where it is adapted to life as a bottom dweller, living and feeding on the seafloor. It is a poor swimmer, but modified fins act as makeshift legs, helping it to 'walk' along the sand. Well, it's more of a froggy waddle, but when a little more speed is required, the batfish can push off with the 'pelvic' fins beneath its body and use its muscular tail to propel itself through the water. The fish also sports a fleshy appendage on the top of its head called an illicium, which contains a chemical-emitting lure that's thought to help it attract the small fish and invertebrates on which it feeds. This fish is enigmatic, it's eccentric, and with no known predators, we should be able to enjoy its Instagram-worthy pout for some time to come. *HP*

GETTY IMAGES, ALAMY X2, BIRGITTE WILMS/NATUREPL.COM ILLUSTRATION: DANIEL BRIGHT

LAURA PRICE, CARDIFF

WERE THE EGYPTIAN PYRAMIDS BUILT BY SLAVES?

Contrary to popular belief, it wasn't slaves who built the pyramids. We know this because archaeologists have located the remains of a purpose-built village for the thousands of workers who built the famous Giza pyramids, nearly 4,500 years ago. I had the good fortune to work on the site in 2005-2006, and it was incredible to watch as the finds came in. There were ancient name stamps and seals – bureaucratic evidence of how the officials kept track of the huge operation to feed and house the workers. Animal bones found at the village show that the workers were getting the best cuts of meat. More than anything, there were bread jars, hundreds and thousands of them – enough to feed all the workers, who slept in long, purpose-built dormitories. Slaves would never have been treated this well, so we think that these labourers were recruited from farms, perhaps from a region much further down the Nile, near Luxor. The labourers would have been enticed by the mix of high-quality food and the opportunity to work on such a prestigious project. Today, many of the highly experienced archaeological workmen at the pyramids come from the same region, though they are paid in hard currency, rather than prime beef and accolades.

Building the pyramids was not an easy job. The skeletons of some of the workmen show that their muscles were under a large amount of strain. But they may not have resented their jobs too much – in graffiti left near the pharaoh Khufu's burial chamber in the Great Pyramid of Giza, they painted the name of their work crew: 'The Friends of Khufu Gang'. ***BH***

ASTRONOMY FOR BEGINNERS

HOW CAN I SPOT THE INTERNATIONAL SPACE STATION?

WHEN: ALL YEAR ROUND

At any given moment, there are up to six humans orbiting 400km above our heads in a huge science laboratory. The International Space Station (ISS) is the Earth's biggest artificial satellite, and it's also a very good reflector of sunlight, making it the brightest object in our sky after the Sun and the Moon.

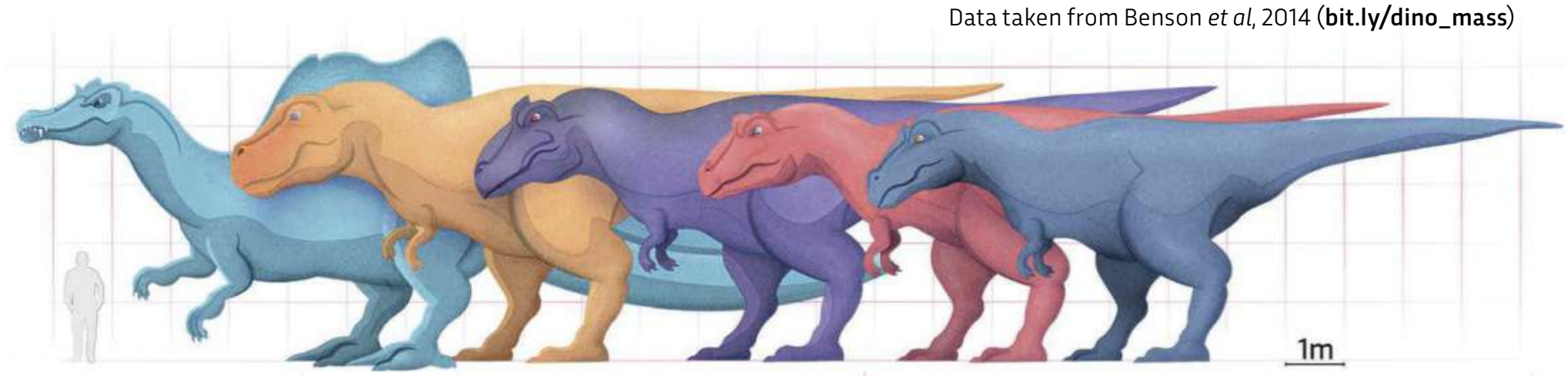
Spotting the ISS with the naked eye is one of the most fun and rewarding stargazing activities – you just need to know when and where to look. The ISS is travelling at a speed of around 28,000km/h (planes, by comparison, fly at around 900km/h), so it whizzes around the Earth once every 90 minutes, and crosses the sky in six minutes or less.

Sighting opportunities range from once a month to several times a week, depending on the path of the ISS's orbit, and the time of year. During northern hemisphere summer, the ISS receives enough sunlight to make it visible at all times of the night. For the rest of the year, the ISS only gets enough light around sunrise or sunset (during the middle of the night, it is too dark against the sky).

To spot the ISS, look for a bright, white spot of light moving quickly across the sky. The light will be constant, so if it flashes, or you see red lights, that's a plane.

To find out when the ISS will be visible near you, enter your location at NASA's 'Spot the Station' website (spotthestation.nasa.gov). It'll tell you exactly when the ISS will be overhead and in which direction to look. You can also sign up to receive alerts around 12 hours before each sighting opportunity. If you live in an area with lots of buildings, look for sightings with a 'max height' of at least 40° – any lower and there's a good chance that the ISS will be obscured. ***AB***

Data taken from Benson *et al*, 2014 (**bit.ly/dino_mass**)

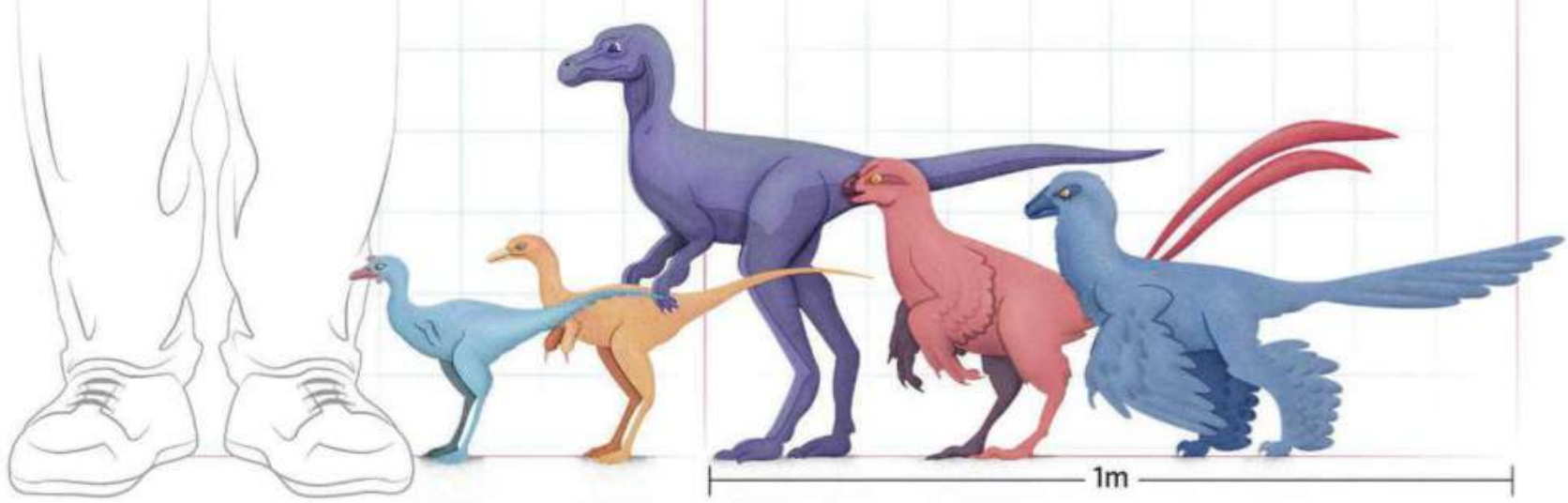


Spinosaurus aegyptiacus (8 tonnes)
Tyrannosaurus rex (7.7t)
Giganotosaurus carolinii (6.1t)
Tyrannotitan chubutensis (4.9t)
Mapusaurus roseae (4.1t)

TOP 5

HEAVIEST AND LIGHTEST THEROPOD DINOSAURS

The theropods were a diverse group of dinosaurs. They walked on two legs, were mostly meat-eaters, and all modern birds are descended from them.



Parvicursor remotus (140 grams)
Ceratonykus oculatus (300g)
Ligabueino andesi (350g)
Epidexipteryx hui (390g)
Microraptor zhaoianus (400g)

MATILDA WICKS, BRIGHTON

WHY DO ROADS SHIMMER WHEN IT'S HOT?

As the sunshine beats down on the road, the road surface becomes hot, making the layer of air above it expand and become less dense. This in turn changes the way light passes through it from points further down the road. However, the effect is not uniform. The rising air is turbulent, so its density and thus optical properties are constantly fluctuating. This is what creates the shimmering effect we see as we look down the road. *RM*

ANDREW BROWN

WHY DO I HAVE LESS OF AN APPETITE IN HOT WEATHER?

All of our metabolic processes generate heat, including digestion. For every 1,000 calories you eat, only 250 are converted into useful energy – the rest ends up as waste heat. In hot weather, your body is already working hard to keep you from overheating, and it doesn't need the extra heat from digesting a big dinner. So your appetite is temporarily dialled back and your body gets more of its energy from stored fat reserves instead. ***LV***

TOM, TOWNSVILLE, AUSTRALIA

WHY DO EGGS TASTE SO DIFFERENT, DEPENDING ON HOW THEY'RE COOKED?

Leaving aside the fact that you might have added milk, oil or seasoning, the different taste comes partly from whether the egg has been beaten. Egg white is less flavoursome than the rich, fatty yolk, so mixing them will change the sensory experience. Browning a fried egg or omelette also changes its taste. This is down to a chemical reaction between proteins and glucose called the Maillard reaction, which creates colour and gives the egg a slightly nutty flavour. Finally, a large part of flavour perception comes from the food's texture, or 'mouthfeel'. So this is another factor in why silky scrambled eggs taste slightly different to a gooey poached egg or a fluffy omelette. ***ED***

QUESTION OF THE MONTH

ROBIN BENDON, WREXHAM

COULD COMPUTERS GET A VIRUS THAT'S AS CONTAGIOUS AND DIFFICULT TO ELIMINATE AS THE CORONAVIRUS?

Our computers have already suffered the equivalent of SARS-CoV-2, several times over. Back in 2000, when the internet was still young, a virus called 'ILOVEYOU' emerged. People received an innocuous-looking email, with an attachment file LOVE-LETTER-FOR-YOU.TXT.vbs. But opening the attachment released not a declaration of adoration, but a 'worm' (a type of virus) that overwrote various filetypes, and emailed copies of itself to everyone in the user's contact list. The virus spread around the world in hours, causing an estimated $15bn in damage due to lost data and time. Because it was easy to modify, it also 'mutated' quickly, and more than 25 versions were soon circulating. ILOVEYOU was not the first or the last computer virus – or even the worst. A worm called 'Mydoom' holds that record – first sighted in 2004, it infected 16-25 per cent of emails at its peak, and cost over $38bn.

As a result of these computer virus pandemics, technology companies have stepped up their security game. 'Inoculation' is provided by frequently updated antivirus software, which detects and prevents infections from the latest viruses. 'Face masks' are provided by firewalls that only let safe network communication through to your computer. And 'social distancing' is provided by security mechanisms called 'sandboxes', which isolate programs from each other and prevent any from infecting each other or the host machine. Every modern computer now has these protections, so a computer virus is less likely to spread as quickly as the coronavirus did, and even less likely to cause such widespread disruption to society. ***PB***

WINNER

Robin wins a Smartibot kit, worth £55. The kit contains all you need to build an AI-enabled, cardboard bot. It can be controlled by the free app, or you can attach your smartphone to the robot and use the AI to make the robot chase objects. **thecraftyrobot.net**

GETTY IMAGES X3, ALAMY ILLUSTRATION: DANIEL BRIGHT

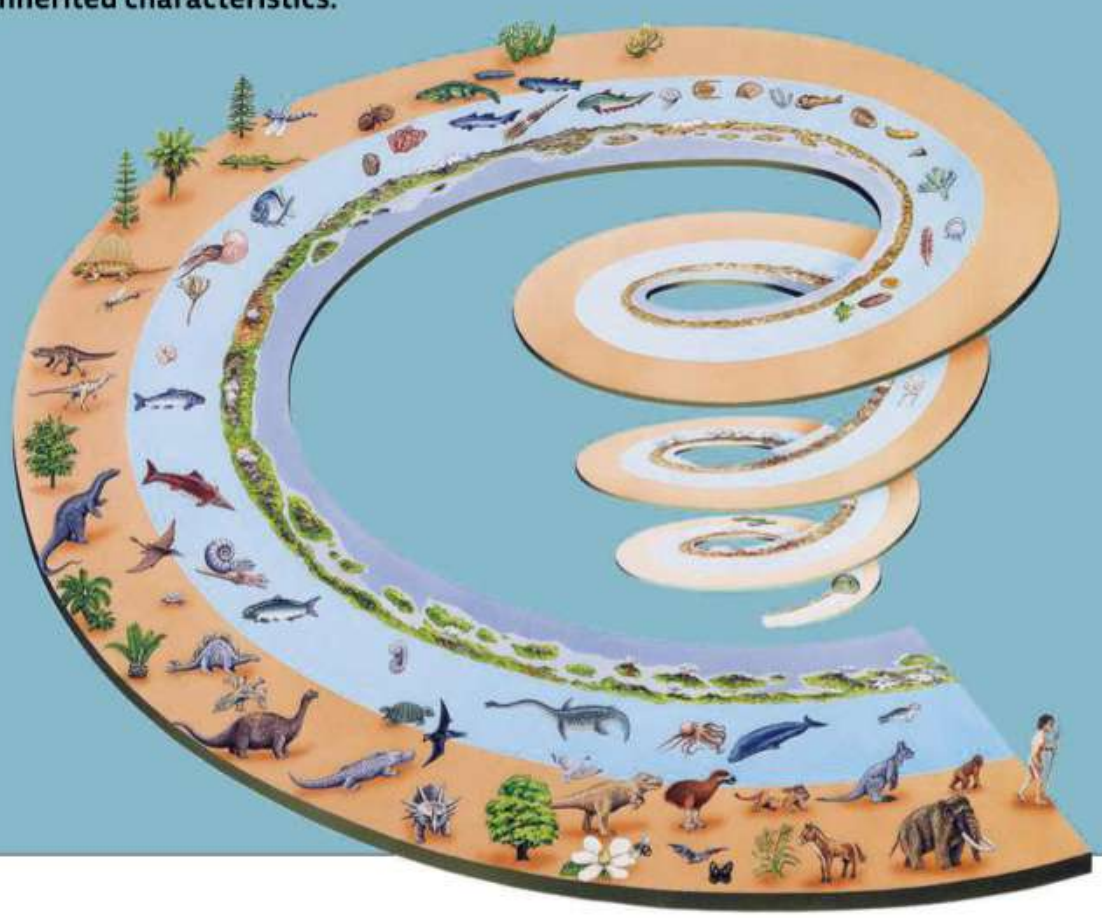
EMAIL YOUR QUESTIONS TO **QUESTIONS@SCIENCEFOCUS.COM** OR TWEET US **@SCIENCEFOCUSQA**

THE EXPLAINER

HOW DOES EVOLUTION WORK?

WHAT EXACTLY IS EVOLUTION?

Plant and animal species come in a huge variety of shapes and sizes. The consensus is that all of these life forms – from alligators to zebras, hawthorn trees to humans – ultimately arose from the same microscopic ancestor that lived about 3.5 to 4 billion years ago. Evolution explains how. It is the process through which populations of living things can physically change through time by picking up new inherited characteristics.



HOW DO WE KNOW THAT HUMANS EVOLVED FROM APES?

The evolutionary changes we see occurring over a few decades are modest: a cricket that evolves to be silent is still a cricket. When evolution unfolds over longer timescales – thousands or millions of years – it can lead to much larger changes in physical appearance. This is why a microbe that lived billions of years ago ultimately evolved into every species alive today.

By carefully assessing physical and genetic similarities, evolutionary biologists can work out which species belong in the same area of the family tree of life. Doing so suggests that humans are more closely related to chimpanzees than to any other species alive today, implying that we both evolved from the same 'parent' species, thought to have lived around 7 to 13 million years ago. Just last year, researchers announced that they had found fossils of an 11.6-million-year-old tree-dwelling ape, which they named *Danuvius guggenmosi*. It had adaptations for walking upright on two legs like we do, but its arms were more suited to hanging from branches, like chimpanzees. This mix of features supports the idea that humans and chimps have a common ancestor, and adds to the abundant fossil evidence that humans really did evolve from (and technically still are) apes.

SCIENCE PHOTO LIBRARY, GETTY IMAGES X2, ALAMY, WIKI COMMONS

WHAT'S GENETICS GOT TO DO WITH IT?

The key word is 'inherited'. Someone's physical appearance might change if they take up bodybuilding. But that sort of change isn't evolution, because a bodybuilder's children will not automatically grow up to be muscular too. By and large, the only way organisms can inherit physical characteristics is if those features are encoded in DNA – the molecule which makes up our genes. This is why genetics is central to evolution.

A key way by which the genetics of populations changes is through a process called natural selection. In a population of a particular plant or animal, some individuals might gain a random mutation in their DNA which causes them to develop a new characteristic that's beneficial in some way. For instance, some peppered moths have a mutation that gives them darker wings. During the Industrial Revolution, these moths were better camouflaged against pollution-darkened trees, so they were more likely to escape the attention of predators, and survive long enough to reproduce and pass on their genes. The number of dark-winged moths shot up. Over time, favourable mutations and the features they encode become more common, and evolution occurs.

CAN WE PREDICT WHAT WILL EVOLVE IN THE FUTURE?

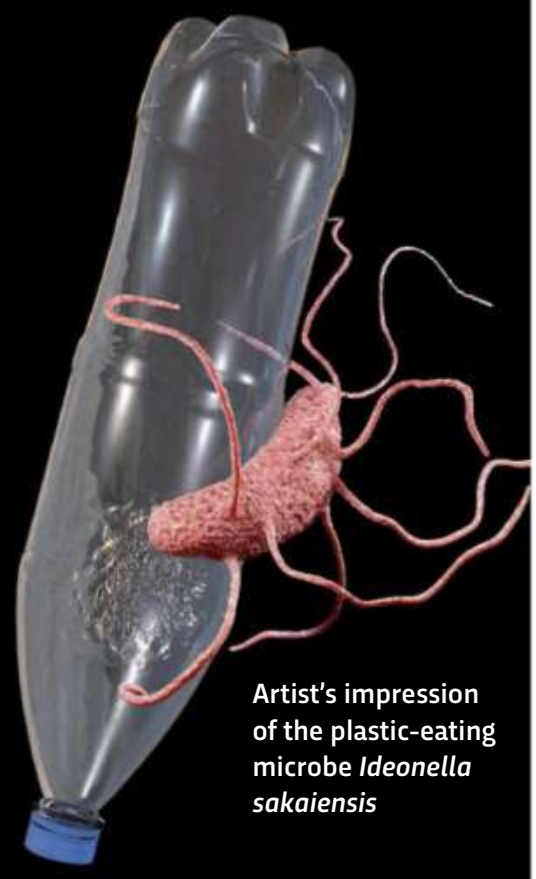
The short answer is no: evolution is not directed towards a goal – it doesn't try to create increasingly complex or intelligent organisms, for instance. But in a sense, evolution is not completely unpredictable.

Today, there are estimated to be almost eight million species of animal and 300,000 species of plant. Their diversity is jaw-dropping, but look more closely and you'll see that there isn't quite as much physical variation between species as you might expect. For example, you could easily confuse a dolphin for a fish: both are aquatic animals with long, streamlined bodies and fins. But dolphins are mammals, and just 50 million years ago their ancestors were small, four-legged, deer-like creatures. Fish, on the other hand, have looked this way for hundreds of millions of years. Biologists think that dolphins look like fish because there are environmental and biological constraints that encourage evolution to repeatedly arrive at similar solutions to a given problem, such as swimming. This is known as 'convergent evolution', and some argue that convergence is so common that evolution can only follow a set number of pathways, which would make it, to some degree, predictable.

WHERE'S THE EVIDENCE THAT EVOLUTION IS HAPPENING TODAY?

There's plenty of evidence. A good example came to light in 2016, when biologists in Japan announced they had discovered a new species of bacteria, *Ideonella sakaiensis*, that had evolved to eat PET plastic. This plastic has only been manufactured since the 1940s, so the bacteria have evolved to eat it in under a century.

Larger organisms can evolve rapidly, too. In the early 1990s, one species of cricket (*Teleogryllus oceanicus*) living on the Hawaiian island of Kauai became the target of lethal parasitic flies. The parasites located their victims by listening out for the crickets' chirps. By 2003, the crickets had evolved: a new genetic mutation that left males physically unable to use their wings to chirp had swept across the island. What had been a population of chirping crickets became a population of mostly silent ones.



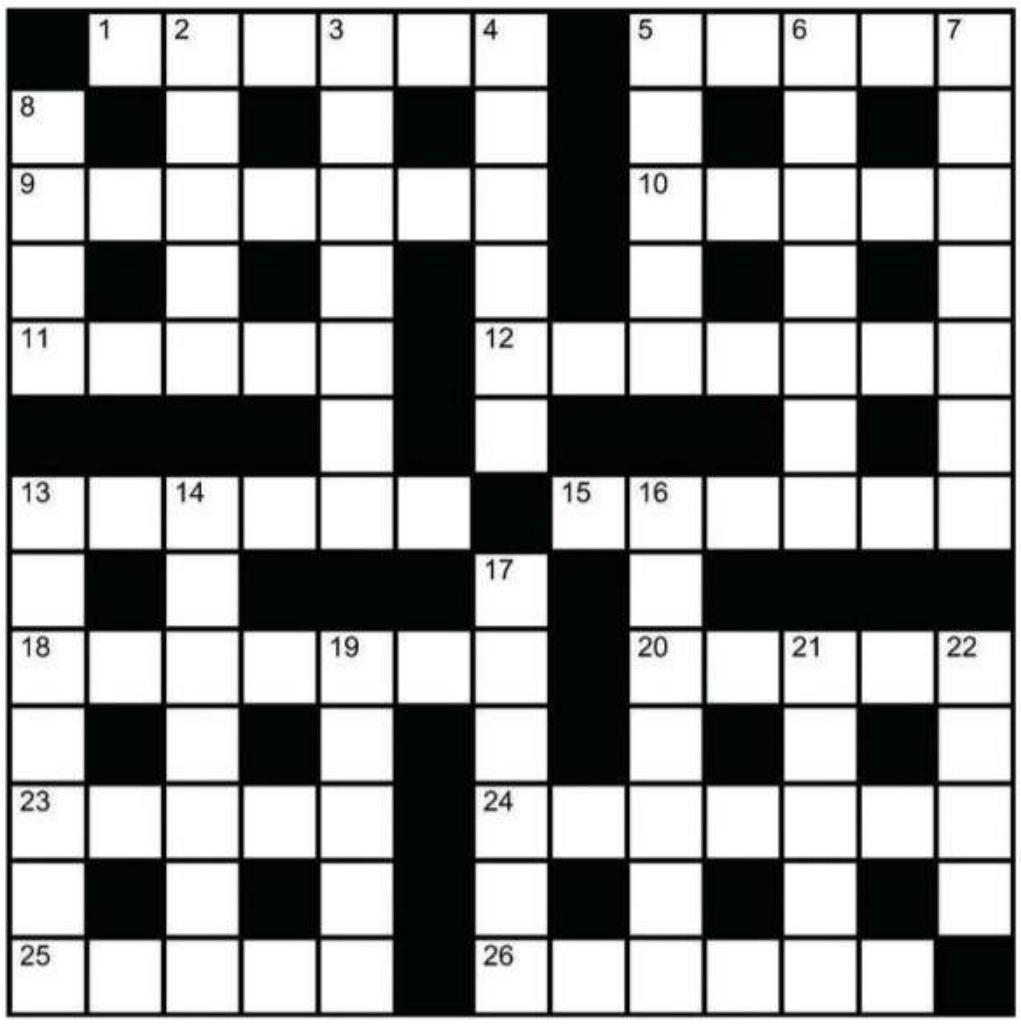
Artist's impression of the plastic-eating microbe *Ideonella sakaiensis*

by **DR COLIN BARRAS**

Colin is a freelance science writer and editor with a PhD in palaeontology.

CROSSWORD

GIVE YOUR BRAIN A WORKOUT



ACROSS

1 A crab managed with one tongue (6)
5 We sat around – hard work (5)
9 Model is quiet at rent review (7)
10 Record vagrant going behind a lake (5)
11 Notes played together in Circle Line (5)
12 Used real tin out of military convenience (7)
13 Bishop acquires modest affliction (6)
15 Muscle radiating around the white bit (6)
18 Laugh, wrapping a pram around a jug (7)
20 Time going from left to right for a drink (5)
23 Bowl – graduate's batting (5)
24 Lie – ours turned out stringy (7)
25 Returning, say, see off some birds (5)
26 The cricket team's legs (6)

DOWN

2 More trouble, old-fashioned at heart (5)
3 The bard worked in one dimension (7)
4 Light is able to get led stray (6)
5 Public transport's turnaround is fashionable (5)
6 European notes diet changes when water recedes (3,4)
7 Paint a mood first (7)
8 The picture contains a story (4)
13 Implore to have a ban set for informal seating (7)
14 Parking in convertible is same dead end (7)
16 Worry about party being a bore (7)
17 Go on about a batter cake (6)
19 Little bit of a snow leopard (5)
21 Girl's first affection for fashion accessory (5)
22 Got up like a flower (4)

ANSWERS

For the answers, visit **bit.ly/BBCFocusCW**
Please be aware the website address is case-sensitive.

GETTY IMAGES

NEXT ISSUE

HOW THE MARTIAN GARDEN GROWS

The quest to grow food on the surface of the Red Planet.

PLUS

ROBOTS FOR EVERYONE

Design and engineering expert Nadya Peek on democratising manufacturing.

THE TRANSPARENT ZOO

We take a look at some incredible animals that have evolved to be see-through.

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Crew members tread carefully along the slanting deck of the aircraft carrier USS *Yorktown* after bomb damage received during the battle of Midway, June 1942

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GETTY IMAGES

A SCIENTIST'S GUIDE TO LIFE

HOW TO GET A GOOD NIGHT'S SLEEP

DO YOU OFTEN FIND YOURSELF LYING AWAKE IN BED, UNABLE TO DROP OFF? FEAR NOT, HELP IS AT HAND FROM SLEEP SCIENTIST **DR ALICE GREGORY**

SLEEP IS REALLY IMPORTANT.
It impacts every aspect of our lives. It's vital for regulating our emotions, weight, immune system and cognitive functioning. When we don't get enough sleep, we can feel terrible.

'EVERYONE NEEDS EIGHT HOURS'.
This is a myth. People vary hugely in terms of their sleep requirements. Some people manage perfectly well with less than eight hours, while others need more.

CONSISTENCY IS KEY.
Stick to a routine with a consistent bedtime and waking time. Your body needs to know what it should be doing and when it should be doing it. This is important for all of us, including babies and young children. If the evening always goes 'story, bath, bed', then they know what to expect.

IT'S NORMAL TO WAKE UP DURING THE NIGHT.
Most people just fall straight back to sleep without realising it. If you can't get back to sleep easily, or if you struggle to nod off in the first place, don't just lie there. Get up and do something else. It's important to associate bed with sleep and not with being mentally awake.

DAYTIME HABITS ARE IMPORTANT.
Exercise helps and it's a good idea to avoid caffeine and alcohol. For some people, even caffeine in the morning can impact their sleep much later. And although a little alcohol can make you feel sleepy, it can also wake you in the night because it makes you need the loo.

STRESS HAS A HUGE EFFECT ON SLEEP.
It's probably one reason why so many people have reported poor sleep during lockdown. Mindfulness, muscle relaxation and breathing exercises can all help, but there's also data to suggest that writing a list before bedtime can help to unload the stresses of the day and aid sleep.

WATCH YOUR SCREEN TIME.
Try to avoid electronics for an hour or two before bed. This is because the content can be arousing and because light is the most important factor for setting our internal body clock. Blue light in particular is disruptive for melatonin, which is the hormone that helps tell our body when it's time for bed. If you use your phone, lower the brightness and use a night setting that filters out blue light.

STAY COOL.
Keep the room temperature at around 16°C to 19°C. It might seem a little Arctic, but the body's core temperature drops just before sleep, so if the room is too hot it can make sleeping difficult.

GIVE TEENAGERS A BREAK.
Adolescents aren't being lazy. They're doing exactly what their biology is requesting of them – staying awake and getting up later. It's a real shame that schools demand such an early start time. During lockdown and the summer holidays, many teenagers were able to revert to their natural sleep pattern, so it prompts the question, is it time for a change? SF

DR ALICE GREGORY
Alice is a sleep scientist at Goldsmiths, University of London, and author of Nodding Off *(£10.99, Bloomsbury Sigma).*
Interviewed by Dr Helen Pilcher.

NEED TO KNOW...

1
If you can't sleep, get up and do something different.

2
Stick to consistent bedtimes and waking times – yes, even at the weekend!

3
Don't nag teens for being lazy, their body clocks are different from adults'.

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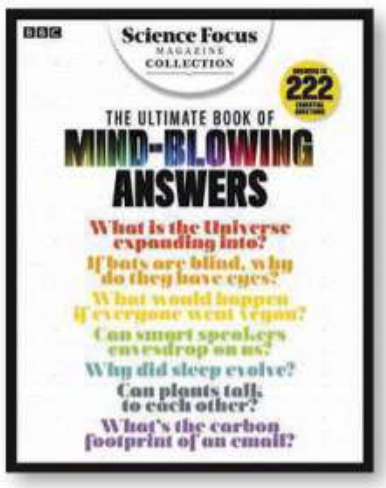
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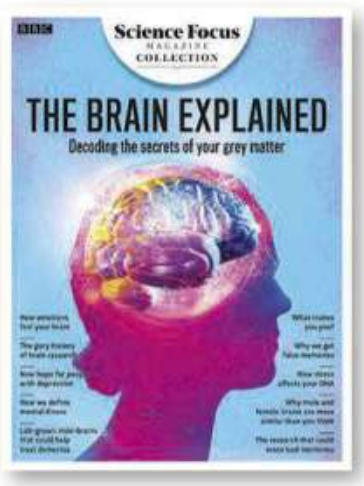

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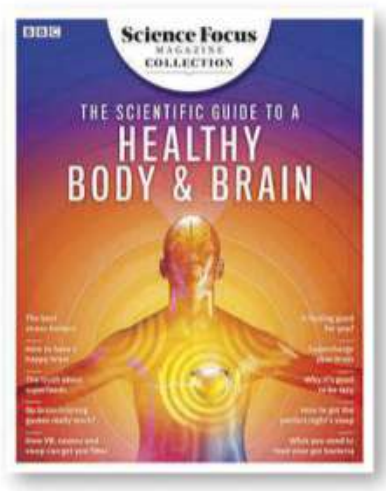

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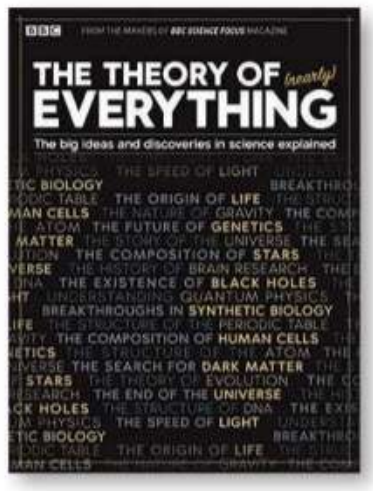

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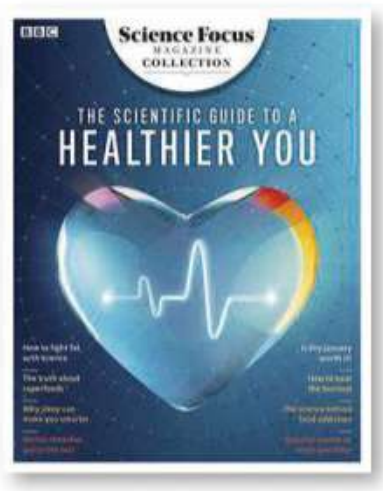

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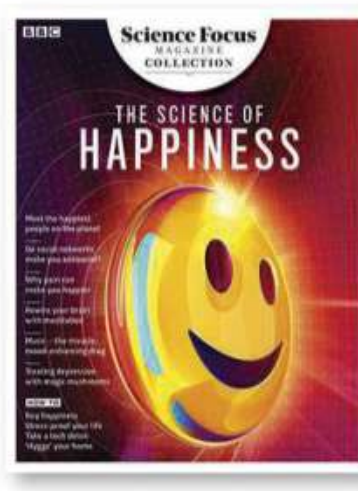

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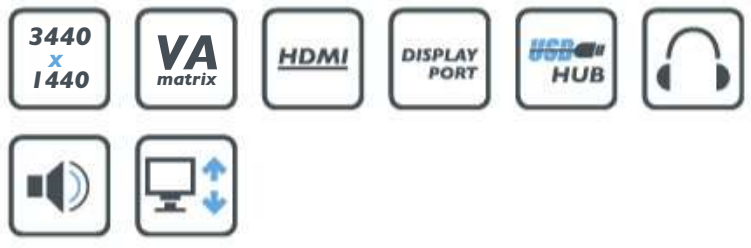

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